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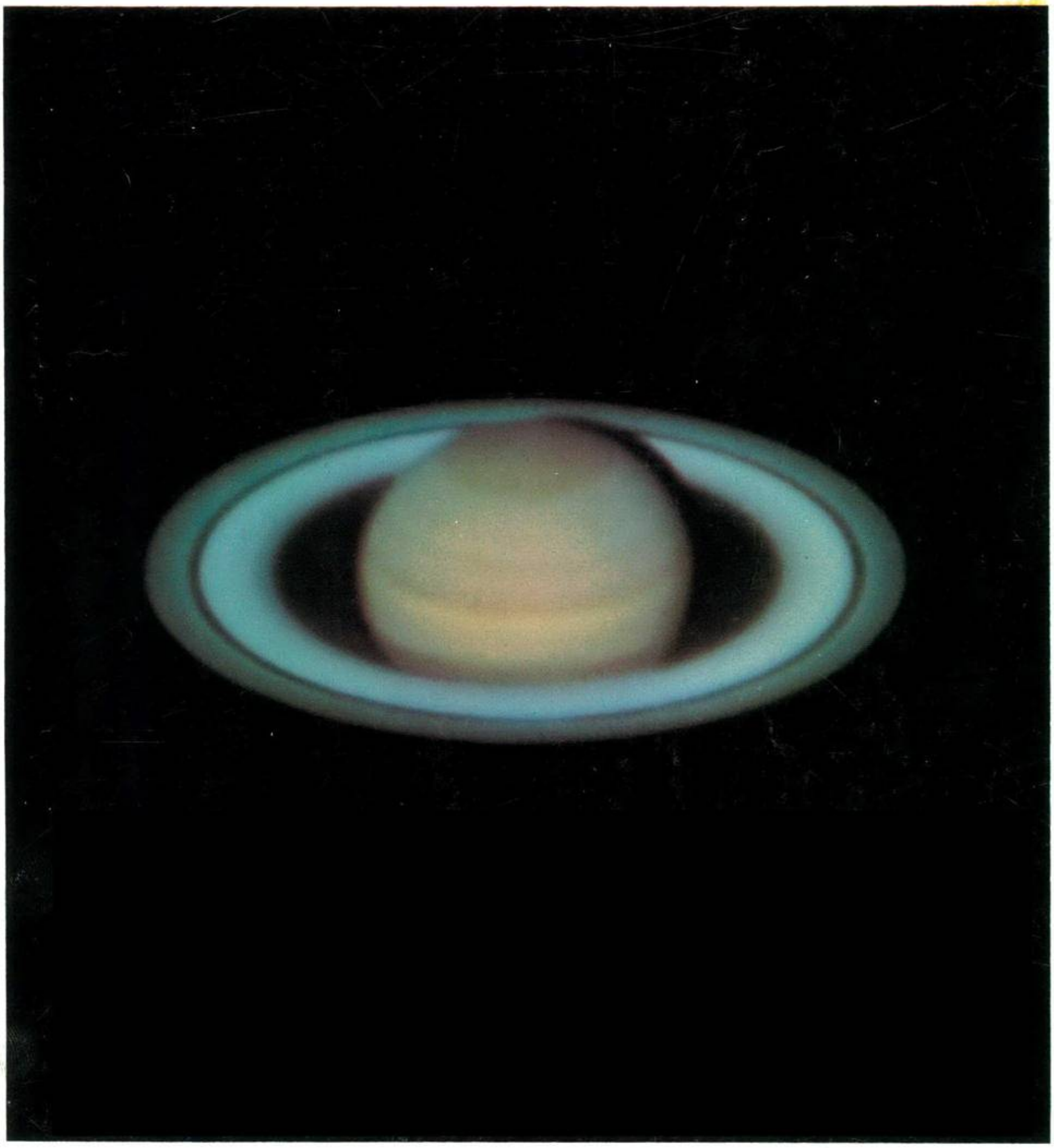

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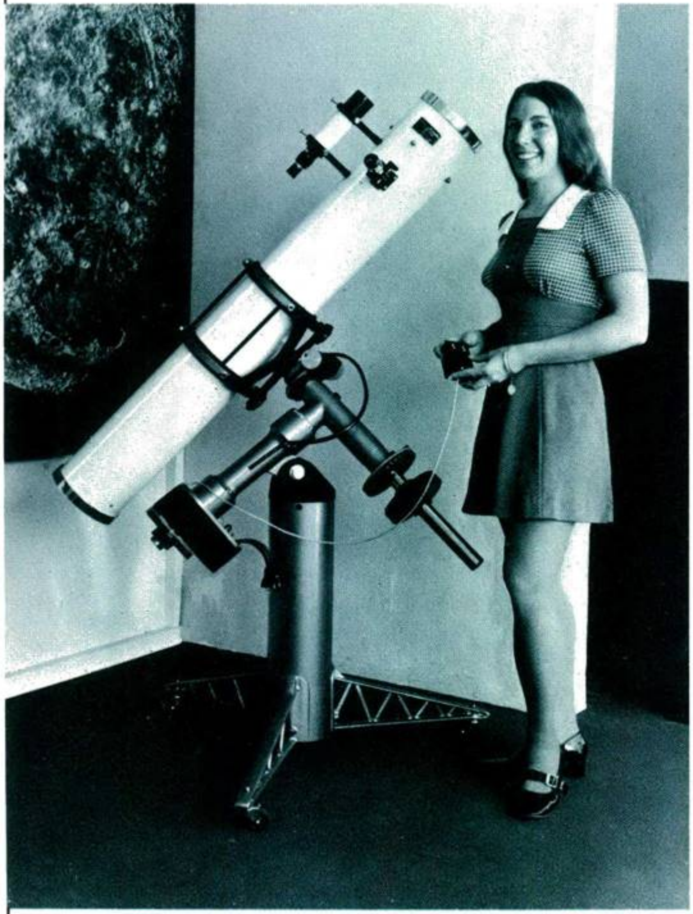

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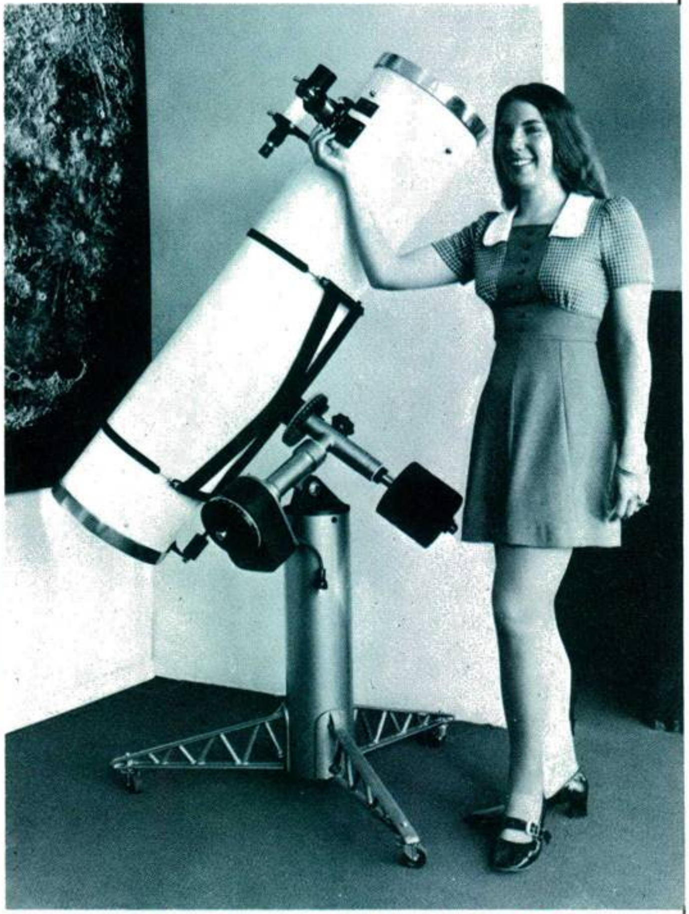

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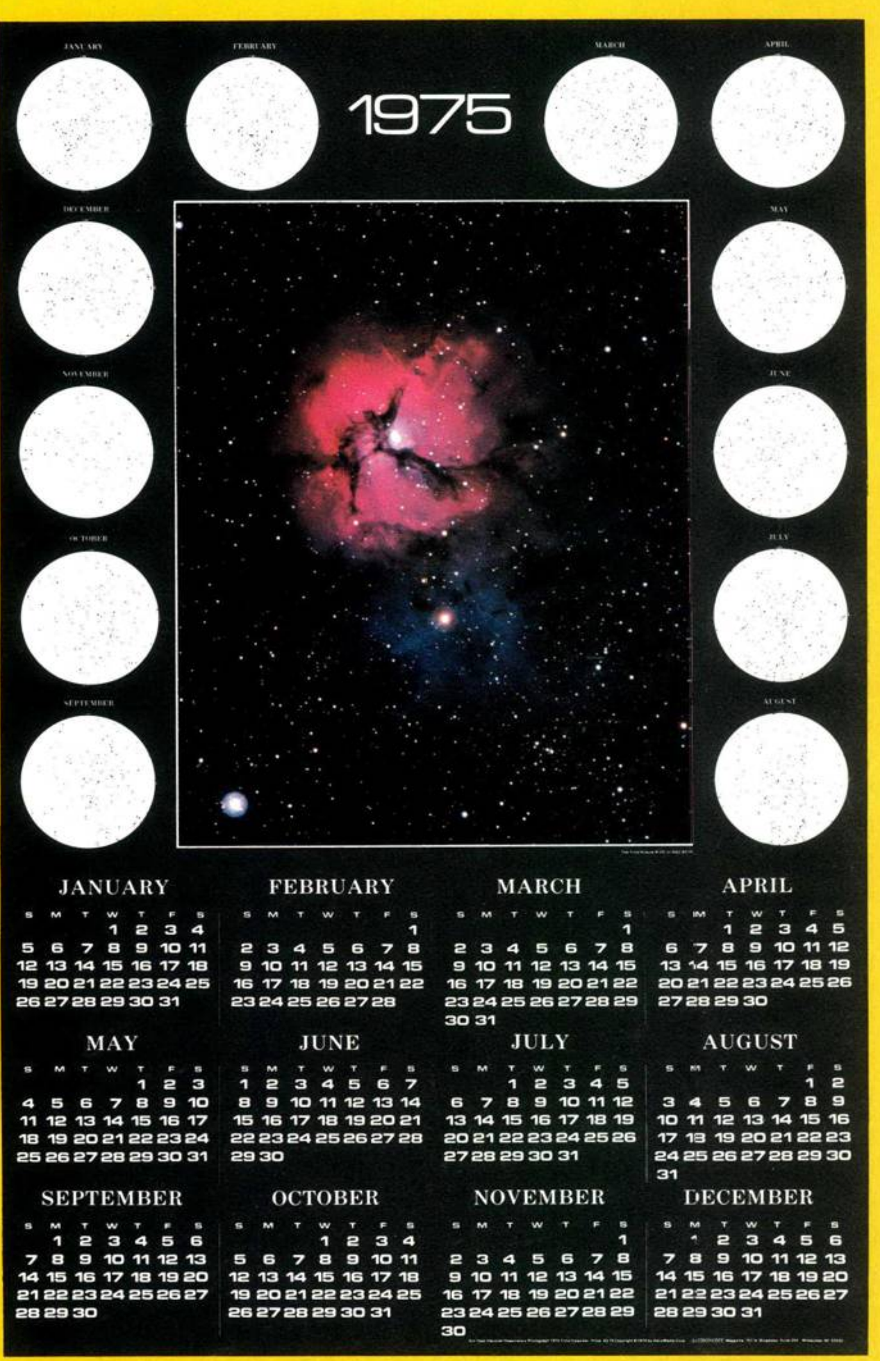

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This first of ASTRONOMY's monthly 80 page issues is dedicated to the memory of Herbert Walther, founder and publisher of CONTRACTOR magazine, who died October 17, 1974 after a 13 month fight against cancer. His avuncular counsel inspired ASTRONOMY's early footsteps and helped pave the road to our current success. The loss of his wisdom and wit is deeply felt.

ASTRONOMY

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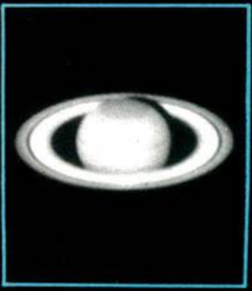

Cover

Lunar and Planetary Laboratory Photograph

Saturn and its spectacular system of rings are the showpiece of the solar system. The unique rings, less than two miles thick, are 170,000 miles wide — 2/3 the Earth-moon distance. This photo shows (for the first time in color) delicate variations in brightness within the two main rings. The inner, dusky or crepe ring can be seen in front of the disk. Saturn itself is striped with pale, but distinct, atmospheric belts that parallel the equator. This issue contains two articles on this remarkable world. Photo data: 61 inch telescope stopped to 40 inches; composite of 16 images selected from over 1,000 taken on March 10, 1974 on Kodak Ektachrome EF film.

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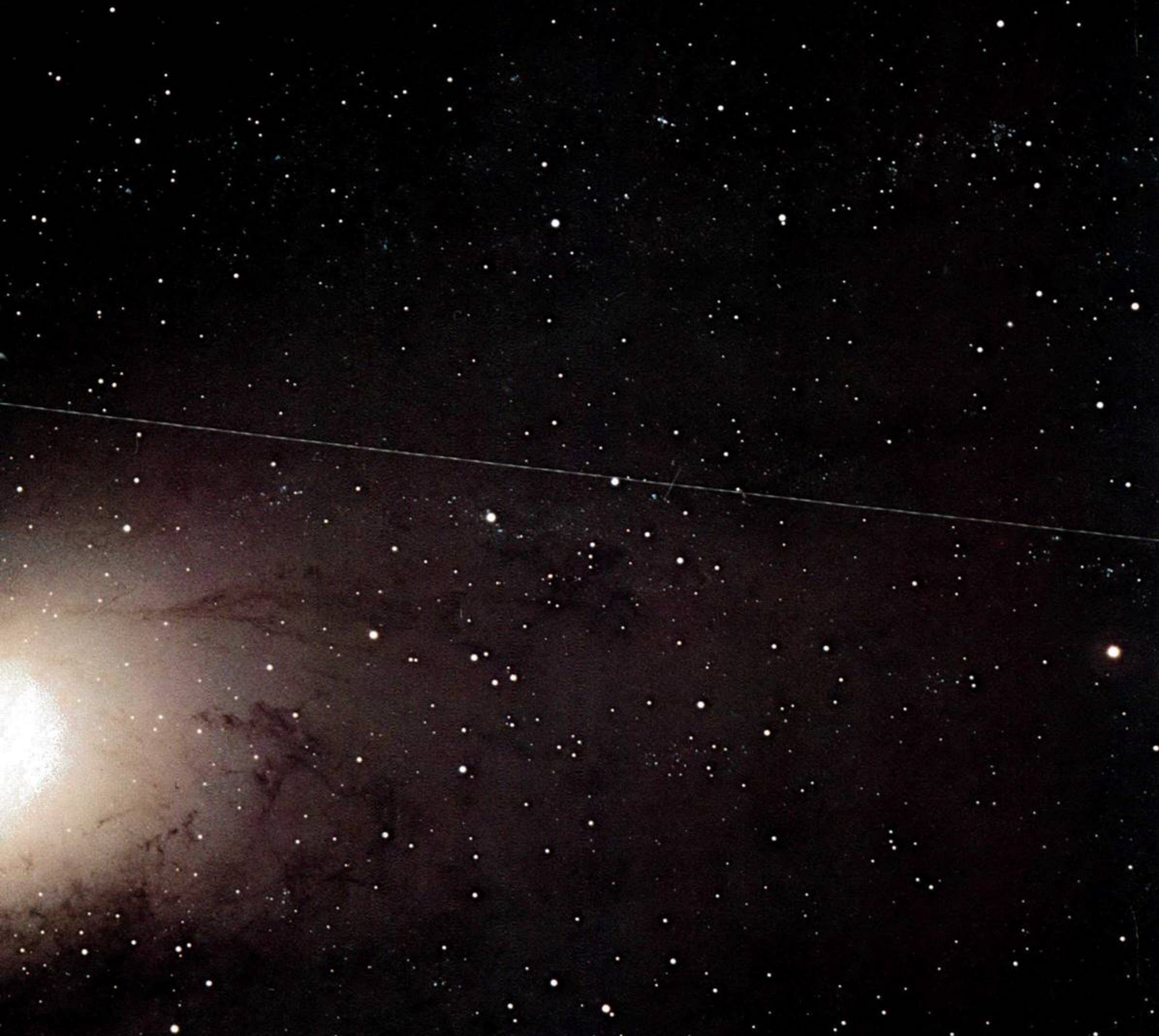
Beyond the

Milky Way

by George O. Abell



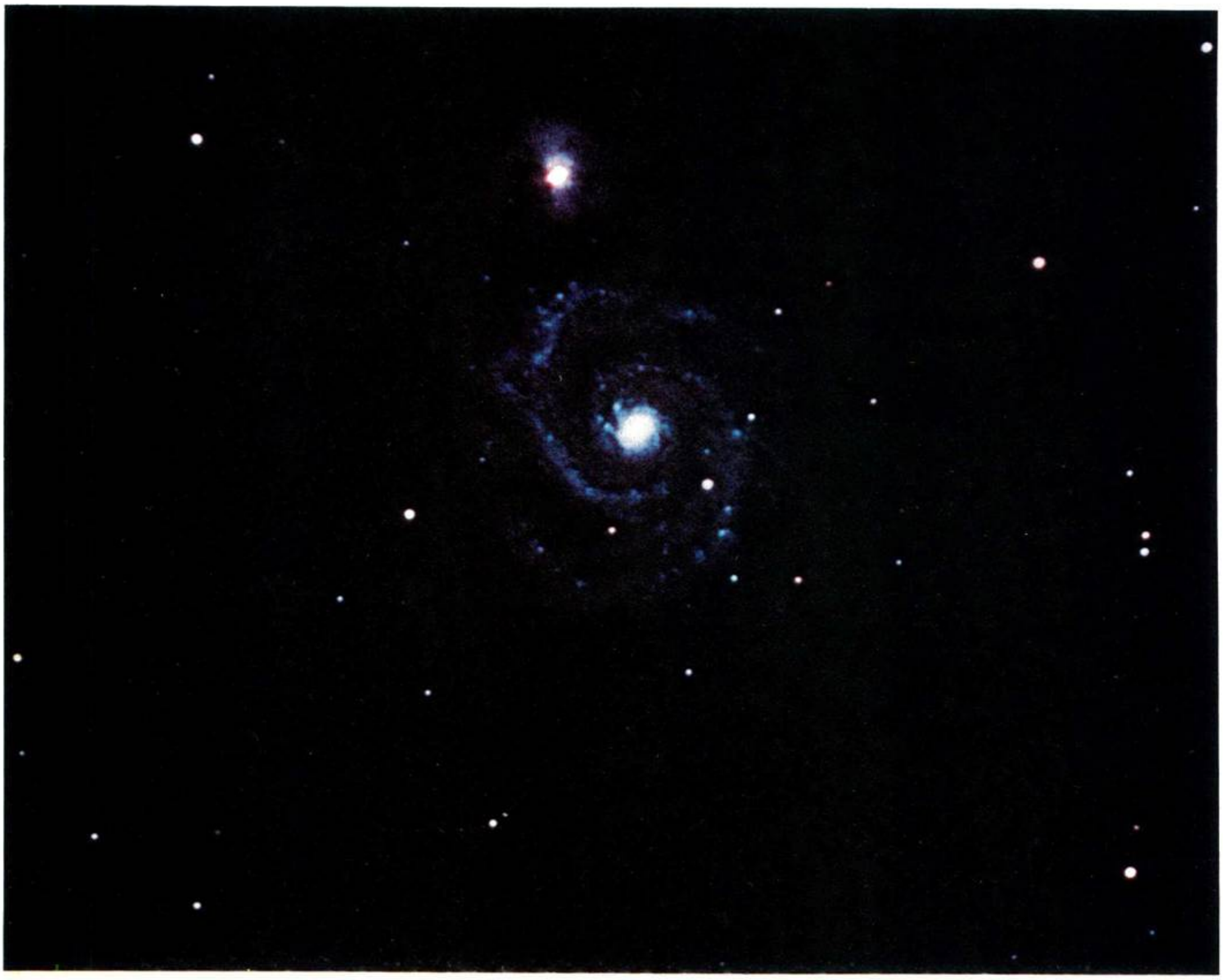
Vast dust lanes silhouetted against the central bulge of the Andromeda galaxy (M-31) obscure some of the billions of yellow suns that give this central zone its golden glow. Farther out from the nucleus, a sprinkling of blue supergiant stars pepper the upper and lower portions of this 158 inch telescope photo. Among those giant suns, an occasional small red blotch can be seen. These are emission nebulae — like the Orion nebula. The outer arms of this nearest of all spiral galaxies are beyond the limits of this photo. The small elliptical galaxy known as M-32 (upper left) is a companion to M-31. During the 30 minute exposure, a small tumbling Earth satellite left its signature on the photo as it strayed in front of the galaxy.

Kitt Peak National Observatory Photograph

Almost all of the stuff of the universe — so far as we know — is concentrated in gigantic assemblages of stars, gas, and dust called galaxies. Galaxies are fundamental units of matter. Yet our realization of their very existence is a bare half century old, and today they present us with some of the most perplexing and bizarre problems of science.

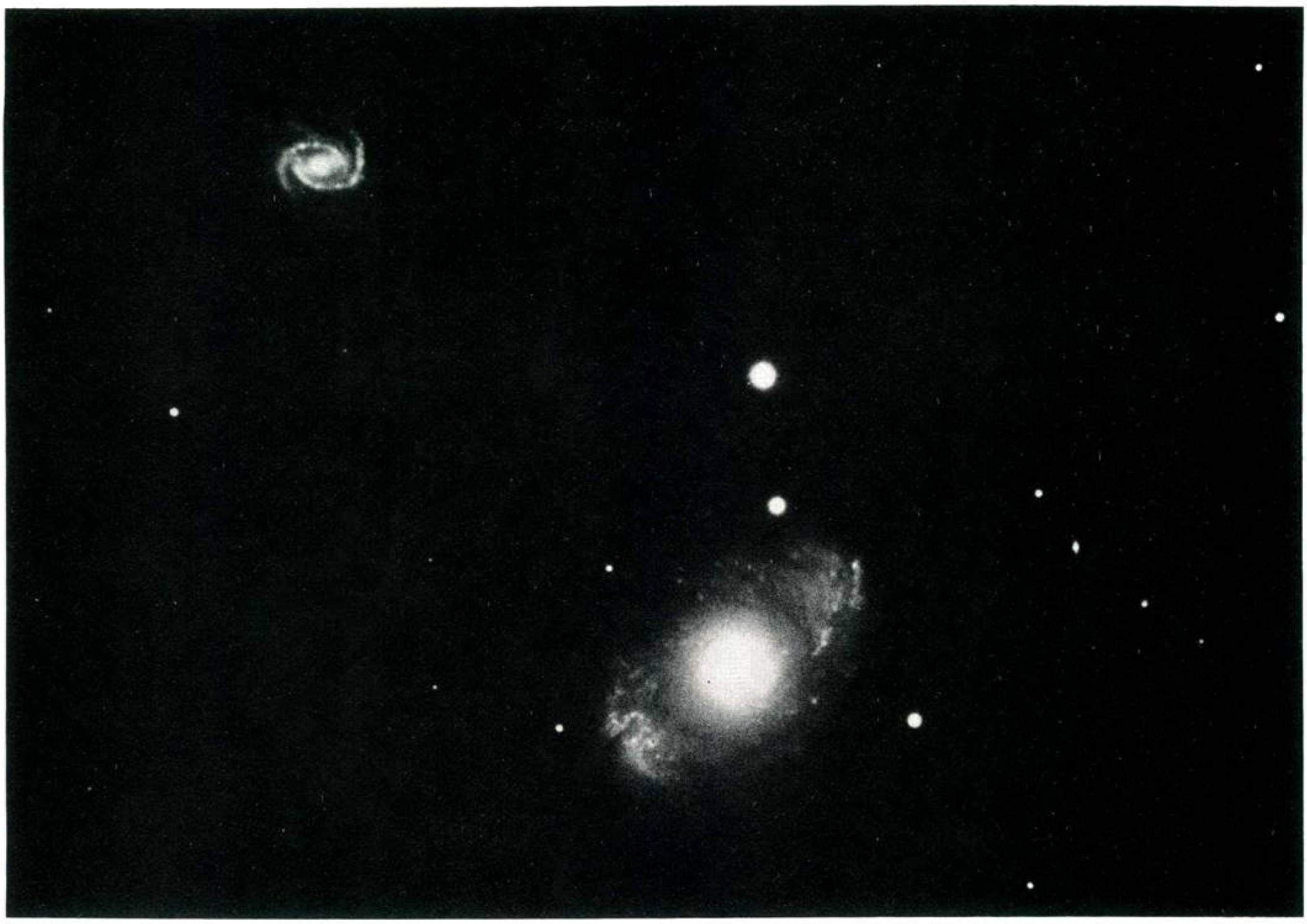
The sun, so central and overwhelming in our solar system, is but one star among a few hundred billion that make up the particular galaxy in which we live. Unfortunately most of our own galaxy is hidden from our view — at least in visible light. Our galaxy is flat like a wheel, and the sun lies close to its central plane. When we look around the sky in the direction of the plane of the wheel — that is, edge-on through it — our line of sight encounters so many stars that most seem to merge together in the distance, producing a glow of light — the Milky Way — stretching in a circle completely around the sky.

When we look into the brightest parts of the Milky Way we see no farther than a few thousand light-years, because the space between the stars is not quite empty but contains vast clouds of extremely sparse gas (mostly hydrogen) intermixed with microscopic solid grains called *interstellar dust.* It is the dust that hides most of our galaxy from view. Although the interstellar material comprises a far higher vacuum than any that can be produced in the laboratory, the dust, like "cosmic smog" extending over hundreds or thousands of light-years, effectively scatters the light from remote stars shin-



Photograph by Evered Kreimer

A twirling island of stars floating in the void — a comparatively nearby example of a spiral galaxy — is shown in this photograph. Looking at M-51 face-on like this we can clearly see the pinwheel structure that characterizes an Sc spiral galaxy. The companion galaxy at the end of one of these arms is not a particularly rare phenomenon — many galaxies have companions. M-51 is 40,000 light-years wide and has perhaps 1/5 the mass of our galaxy. This is one of the few galaxies whose spiral structure can be seen in moderate sized small telescopes.



Hale Observatories Photograph

One of the nearest Seyfert galaxies is NGC-4151 — a type of galaxy characterized by abnormally high infrared radiation emitted from the nuclear regions. The spiral galaxy to the upper left is a more distant background object. Some astronomers believe this class of object exhibits an energetic phenomenon somewhere between quasars and normal galaxies.

ing through it, dimming them to invisibility. It was only after the pioneering investigations of Harlow Shapley in the 1920s, and the more recent studies by radio astronomers (radio waves travel unhindered through the dust), that we learned that the Milky Way galaxy is at least 100,000 light-years in diameter, and that the sun revolves about its center at a distance of some 30,000 light-years completing its orbit in a "galactic year" of about 200 million terrestrial years.

With the understanding of the nature of our own galaxy coming into focus so recently, it is no wonder that astronomers were slow to recognize that the universe is dotted with at least a billion other galaxies — more or less similar to our own. Thousands of them, to be sure, have been catalogued by William Herschel and his successors over the past two centuries. They can be seen when we look at right angles to the Milky Way, out through the thin dimension of the galaxy (see illustrations page 18). Many galaxies appear telescopically like tiny silvery mothballs, or like slightly flattened spheres. Others are flat and wheel shaped like our own. Often the latter display pinwheel-like bright arms spiraling outward from central hubs. But prior to the 1920s there was no way of knowing that these nebulous patches of light were vast stellar systems. (Some astronomers, however, and even philosopher Immanuel Kant in 1755, had speculated on the possibility.)

Distances to Galaxies

Not until after the construction of large telescopes — especially the great reflectors on Mount Wilson early in the 20th century — did astronomers have any means (even though crude) of measuring distances to other galaxies. With these telescopes, photographs were made that revealed images of the brightest individual stars in relatively nearby galaxies. The problem was to determine what kinds of stars those were, and thus how intrinsically bright they were. Then we could calculate how far away those galaxies would have to be to account for the apparent faintness of the stars.

The first clue came in 1924 when Edwin P. Hubble, at the Mount Wilson Observatory, discovered that some of the resolved stars varied in light, and showed the characteristic behavior of Cepheid variables — well-known giant pulsating stars in our own galaxy. Hubble knew that the

A Note on Numbers and Distances in Astronomy

How big is a million — or a billion? A million one dollar bills would form a pile nearly as high as the Great Pyramid. But a billion (one thousand million) greenbacks would make a stack that would soar 10 times higher than Mt. Everest. And a trillion one dollar bills? (One trillion is a million million, or one thousand billion.) The trillion pile would reach over 1/4 of the way to the moon!

Or you can think of it this way: A million seconds is 12 days, but a billion seconds adds up to over 31 years. And a trillion seconds is 300 centuries — longer than the history of civilized man.

Like nothing else in human experience, astronomy encompasses distances, ages and sizes so enormous that it is nearly impossible to get even an approximate mental image of any of them.

Except for the quasars, galaxies are believed to be the most distant objects known. Since our main article deals exclusively with these huge and remote systems it may be helpful if we devise models to bring some of these monstrous numbers into perspective.

We'll start near home. Imagine the sun as a one inch sphere, somewhat smaller than a golf ball — about the size of a walnut. Earth then becomes a speck of dust about eight feet away with a smaller speck — the moon — nestled beside it, 1/4 of an inch away. Jupiter is a small pea just under 40 feet from the one inch sun. A microscopic speck of dust 300 feet from the sun is Pluto, outermost planet of the sun's family. The nearest star, Alpha Centauri (a triple star system), is now two walnuts and a marble — 410 miles away! You couldn't conveniently walk to the nearest star even if the universe were reduced to this microscopic scale.

But the Milky Way galaxy contains a few hundred billion stars and is 100,000 light-years wide. On our scale the galactic width would be about nine million miles — about 40 times the actual distance to the moon!

Already things are getting unmanageable, so let's reduce our scale even more. If the stars could be shrunk to microscopic specks so tiny that even gigantic Betelgeuse (800 times the sun's diameter) was less than one inch across, the space between them would shrivel to an average of 1/2 mile or so. Now the Milky Way galaxy becomes about as wide as the true size of Earth (8,000 miles). Our nearest major neighbor, the Andromeda galaxy, is now only a little over 1/2 the true Earth-moon distance from us.

If, like some god, we could stroll through this miniature universe we could walk from one star to another in only a few minutes. But even here it would take more than a lifetime to walk between galaxies.

Let's make one final reduction: The Milky Way galaxy is now small enough to hold in your hand — a delicate disk of subatomic sized stars. The Andromeda galaxy is only slightly larger, not quite within reach at its scaled down distance of seven feet. In all directions you perceive the universe of galaxies ranging from basketball sized giant ellipticals down to virtually invisible irregulars and baby ellipticals. Yet even here the scale of the universe defies our senses. Here, with only a few steps between galaxies, there are so many that they fill a volume of space 10,000 times larger than the interior of the Houston Astrodome!

Cepheids were intrinsically hundreds of times as bright as the sun. Thus, from the feeble light we receive from those stars in other galaxies, Hubble was able to calculate the first galaxian distances.

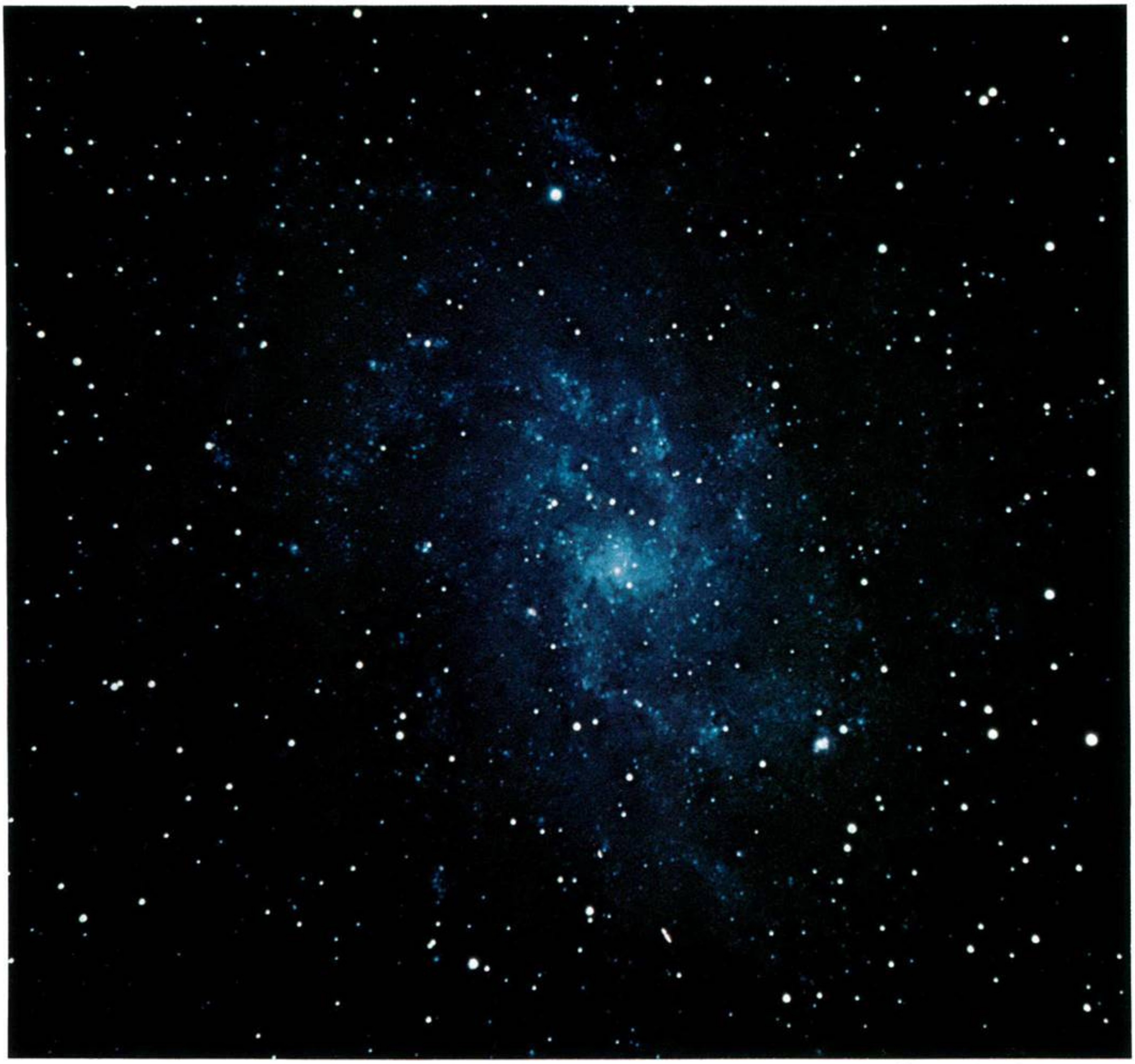
Unfortunately, even the Cepheids are bright enough to see in only about 30 of the nearest galaxies. However, once distances to a few galaxies were known from their Cepheids, astronomers could calibrate the intrinsic brightnesses of other indicators of distance — the very brightest stars in the galaxies, the occasional novae that occur in them, star clusters, or even glowing gas clouds (like the Orion nebula in our own galaxy). Then distances to more remote galaxies could be found from the apparent faintnesses of these objects in them, or — in the case of gaseous nebulae — from their apparent sizes as well.

For still more remote galaxies (the overwhelming majority), we do not even see the very luminous individual objects in them. The best we can do is estimate their distances by still more indirect techniques involving the measurements of the total light outputs of different kinds of galaxies. Such methods indicate rough distances to at least some kinds of galaxies.

Still further information is provided by the motions of galaxies. All are much too far away for us to see them moving in the sky, but we can derive one component of their motions — namely, how fast they approach or recede from us. This kind of motion is called *radial velocity*, and is determined from the *Doppler effect*. If a light source approaches us, the waves of light it emits appear crowded closer together as they come to us; hence we see those wavelengths of light as shortened. If the source recedes from us, the light waves from it are spread out — so the light we see is at longer than normal wavelengths. (This same Doppler effect applies to sound as well as to light, and accounts for the higher than normal pitch of the horn of an approaching automobile, and the lower than normal pitch of the horn of a receding one.) We can detect the Doppler shift, and hence radial velocity, of a star or galaxy by analyzing the spectrum of its light.

In the 1920s, Hubble and Milton Humason (also at Mount Wilson) studied the radial velocities of a number of galaxies of known distance. In 1929 they announced the extremely important observation that all but a few nearby galaxies move away from us, and at speeds that are greater in proportion to their distances. This is the famous *Hubble law.* From the Hubble law we can estimate the distance of a remote galaxy by observing its radial velocity. It is found that the radial velocity of a galaxy is about 10.5 miles per second for every million light-years of its distance. Thus a galaxy with a radial velocity of, say, 1,050 miles per second would have a distance of about 100 million light-years.

The Hubble law cannot apply precisely to the most distant galaxies, however, for the exact form of the law depends on the evolution of the entire universe. Thus we must still find more direct ways



Photograph by Evered Kreimer

Along with the Andromeda galaxy, M-33 is a member of the Local Group and has about four percent as many stars as our galaxy. The blue color of M-33 and M-51 (page 8) is due to the light of newly formed blue supergiant stars that populate the spiral arms of galaxies. This and the photo on page 8 were taken through a 12 inch Newtonian reflector.

A

B

C

D

of learning distances to the very farthest galaxies — a problem not yet solved. Nevertheless, the Hubble law is extremely important to the study of cosmology as it provides the observational evidence that the universe is expanding. But this is a topic for another article.

If galaxian distances are hard to find, and if our present estimates are rather uncertain, we are still much better informed than astronomers were more than a half century ago when our own galaxy was thought to be the entire universe. We know, for example, that only a tiny handful of galaxies lie within a million light-years, and that most of the many millions that leave images on our telescopic photographs are billions of light-years away!

These four titanic cities of stars represent some of the range in galaxy sizes and shapes. (A) One of the most massive spiral galaxies known, M-104 is believed to contain six times as many stars as the Milky Way galaxy. Dust laden spiral arms slice in front of the brilliant nucleus as we view this system nearly edge-on. (B) Enigmatic M-82 is a galaxy which some astronomers have suggested suffered a monstrous internal explosion some two million years ago. An alternate recent viewpoint is that the galaxy is plowing through a gigantic intergalactic dust cloud. (C) The arms of NGC-7217 are tightly wound around the luminous central bulge of this Sb type galaxy. (D) NGC-205 is an intermediate elliptical galaxy, smaller and much nearer than the three galaxies just described. A companion to the Andromeda galaxy, it is about the same size as M-32 which is seen in the upper left on page 6.

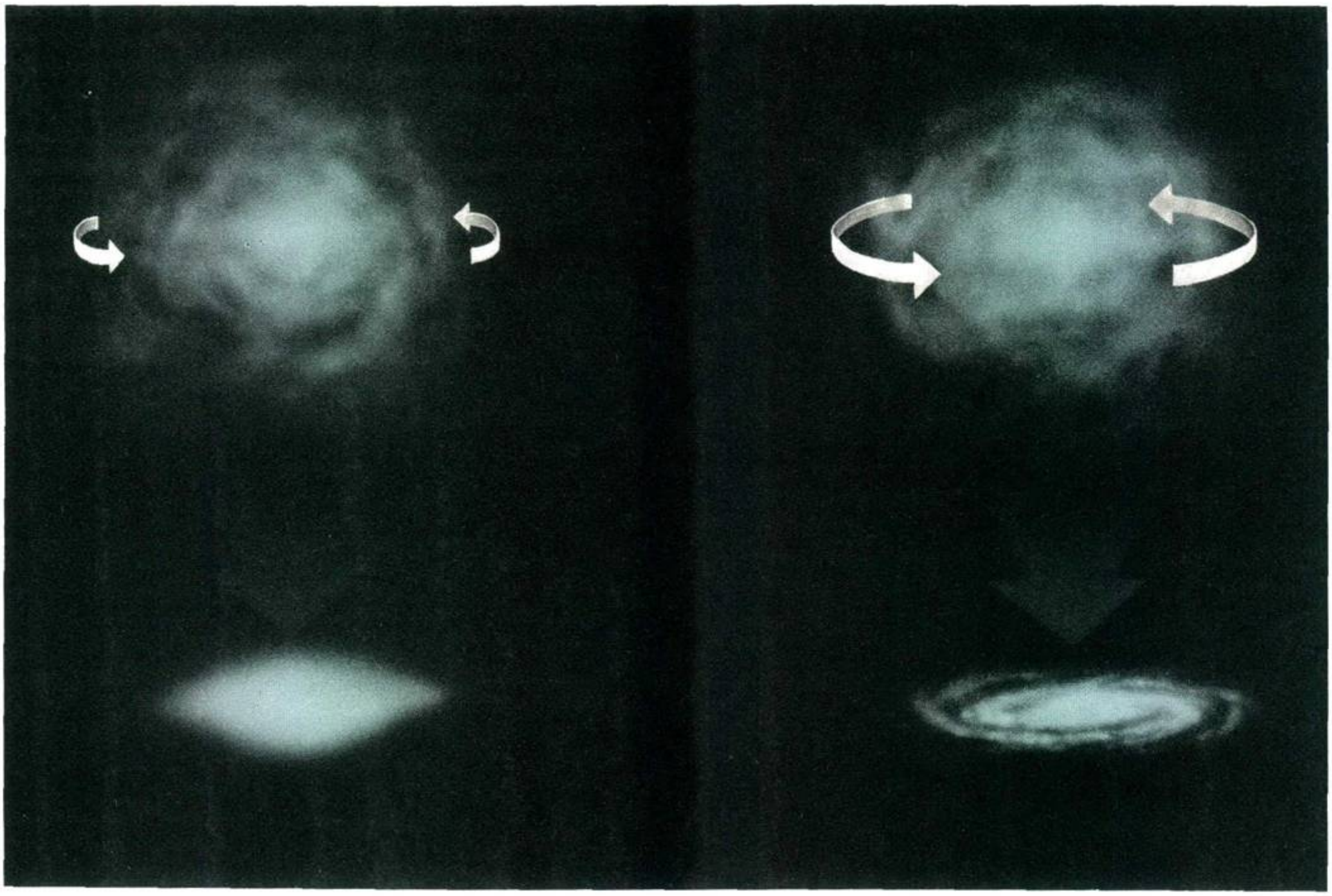
Photograph by Orien Ernest (A)   Lick Observatory Photograph (B)
U.S. Naval Observatory Photographs (C&D)

Distribution of Galaxies in Space

Hubble also made the first thorough, systematic investigation of the distribution of galaxies. In the 1930s he counted images of galaxies on telescopic photographs of more than a thousand sample regions of the sky. From his counts he estimated that about 100 million galaxies are bright enough to observe with the Mount Wilson 100 inch telescope alone. He found (as have more recent investigators) that on the large scale, galaxies are distributed more or less uniformly through space to the greatest depths that have been probed.

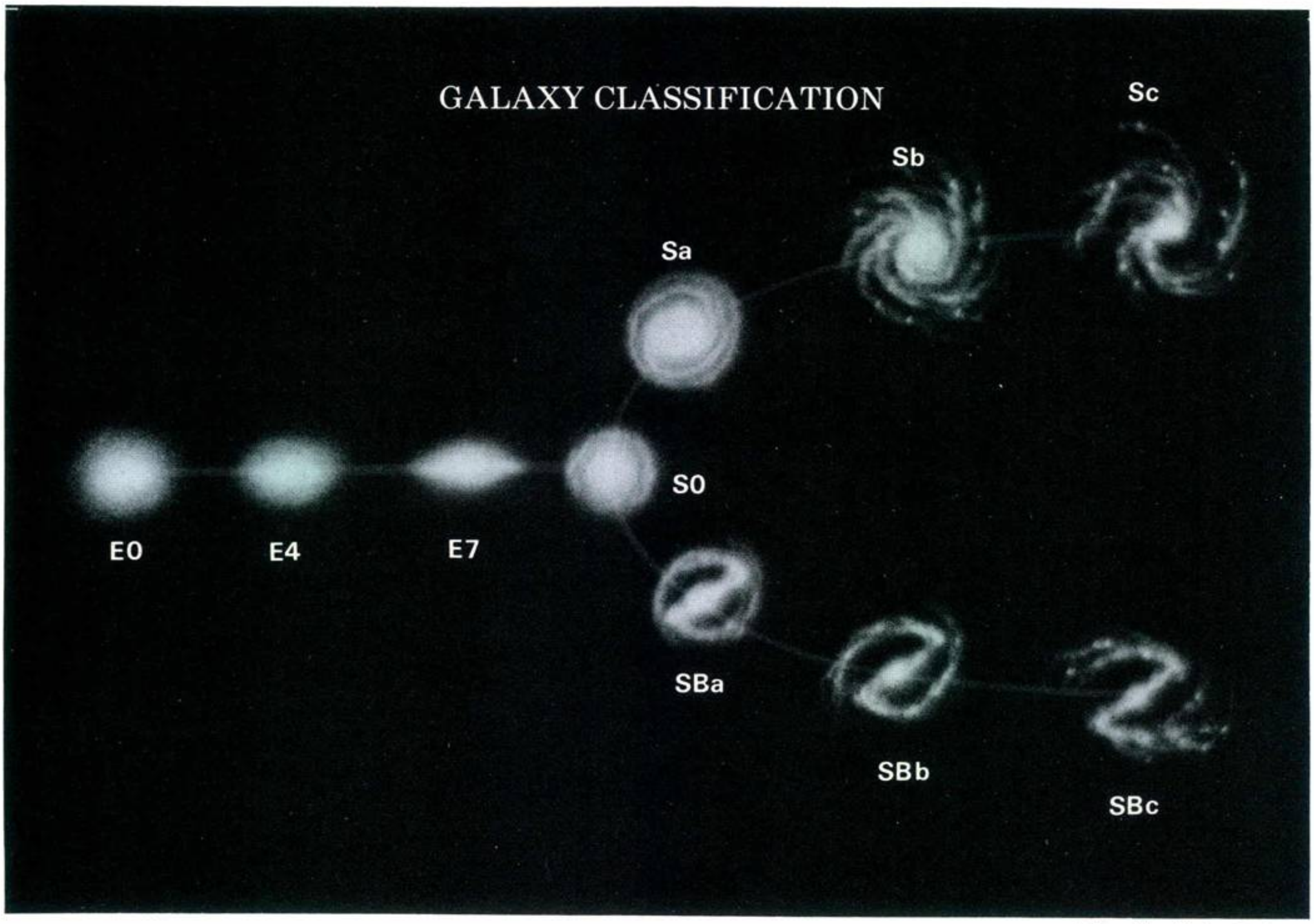
On the small scale, on the other hand, Hubble found a tendency for galaxies to occur in clusters. Today we think that probably all galaxies are in clusters — or at least were formed in them. Our own galaxy is a member of a small cluster of about 20 galaxies spread over a region about three million light-years across. We call our cluster, rather affectionately, the Local Group.

Within 10 million light-years there are several other small groups of galaxies, and on photographs



Artwork by Victor Costanzo

Current theory suggests that all galaxies formed from immense clouds of gas — mainly hydrogen. The rotational momentum of the cloud determines whether the resulting galaxy will be an elliptical or the flatter spiral.



Artwork by Victor Costanzo

The vast majority of galaxies can be classified by their appearance. The system used today originated nearly 50 years ago with Edwin Hubble. According to this classification, the ellipticals are graded from spherical (E0) to substantially flattened spheres (E7). Still more flattened are the more rapidly rotating spirals. They are further subclassified by "tightness" of the pinwheeling arms. Examples of many of these classifications are illustrated in this article.

like those made with the Mt. Palomar 48 inch Schmidt telescope we can recognize many thousands of such groups. About 60 million light-years away lies the nearest fairly rich cluster — the Virgo cluster, with many hundreds of member galaxies. Still farther, about 400 million light-years away, we find the nearest of the great clusters — the Coma cluster, with thousands of members. Nearly 3,000 such great clusters have been catalogued by the author; they lie at distances of up to four billion light-years. We would never recognize our Local Group at so great a distance; yet a few extraordinarily rich clusters have been found nearly twice that far away!

When we speak of these great distances, we are also speaking of things far in the past. We see remote galaxies as they were long ago. The light we see today began its journey through space to us at a previous time equivalent to the galaxy's distance. Thus we see an object a billion light-years away as it was a billion years ago. We see the most remote known clusters of galaxies by light that left them long before the sun and planets of our solar system were in existence. We see even the neighboring Andromeda galaxy as it was 2,000,000 years ago — when man was just emerging on this planet!

The Zoo of Galaxies

Most galaxies fall into one of two general classes: *spirals* and *ellipticals*. Life is seldom quite that simple, though. A small percentage of galaxies do not conform to such a classification scheme, and are called *irregular*. Also, as we shall see, some galaxies — while superficially resembling spirals or ellipticals — have exceptional properties; these are the ones that excite a great deal of current interest.

Most galaxies, though, can be classed as elliptical. They range from approximately spherical in shape through ellipsoidal systems of varying degrees of flatness. None, however, is so flat as to have the shape of a disc or wheel, as does our own galaxy.

Elliptical galaxies include the largest and most massive, and also the smallest galaxies known. The largest ellipticals are usually found in rich clusters of galaxies. Sometimes a cluster is centered on a gigantic elliptical galaxy. An example is NGC-6166, at the center of the cluster Abell 2199 (the notation refers to the author's cluster catalog). Such a supergiant galaxy probably contains over 10 trillion stars, and is at least 300,000 light-years across.

At the other extreme are the dwarf elliptical galaxies; they are probably the most common kind of galaxy. Our Local Group contains nine of them (including three near M-31 that were discovered by Sidney van den Bergh three years ago). These are called Sculptor type systems, after the prototype and the first to be discovered in the constellation Sculptor. Such pigmy galaxies contain only a few million stars, and are typically only about 5,000 light-years across. Neighboring groups of galaxies are also rich in dwarf ellipticals. And although we cannot observe them in the more remote great clusters, we suspect that they are common there too.

From observations we find that the brighter the elliptical galaxies, the less common they are. Thus, giant elliptical galaxies are rare, and Sculptor type systems are extremely common — among galaxies. All elliptical galaxies, however, are alike in that they do not contain large amounts of interstellar material, and do not contain young stars. They appear to have a stellar population that suggests that their stars were all formed many billions of years ago.

The spiral galaxies are a marked contrast. They are flat, rotate rapidly, and contain extensive interstellar matter in the form of gas and dust. This interstellar material has been organized — presumably by the rotations of the galaxies — into arms that spiral out from a central nuclear bulge of stars. Spirals are thus galaxies in which all of the matter is not condensed into stars.

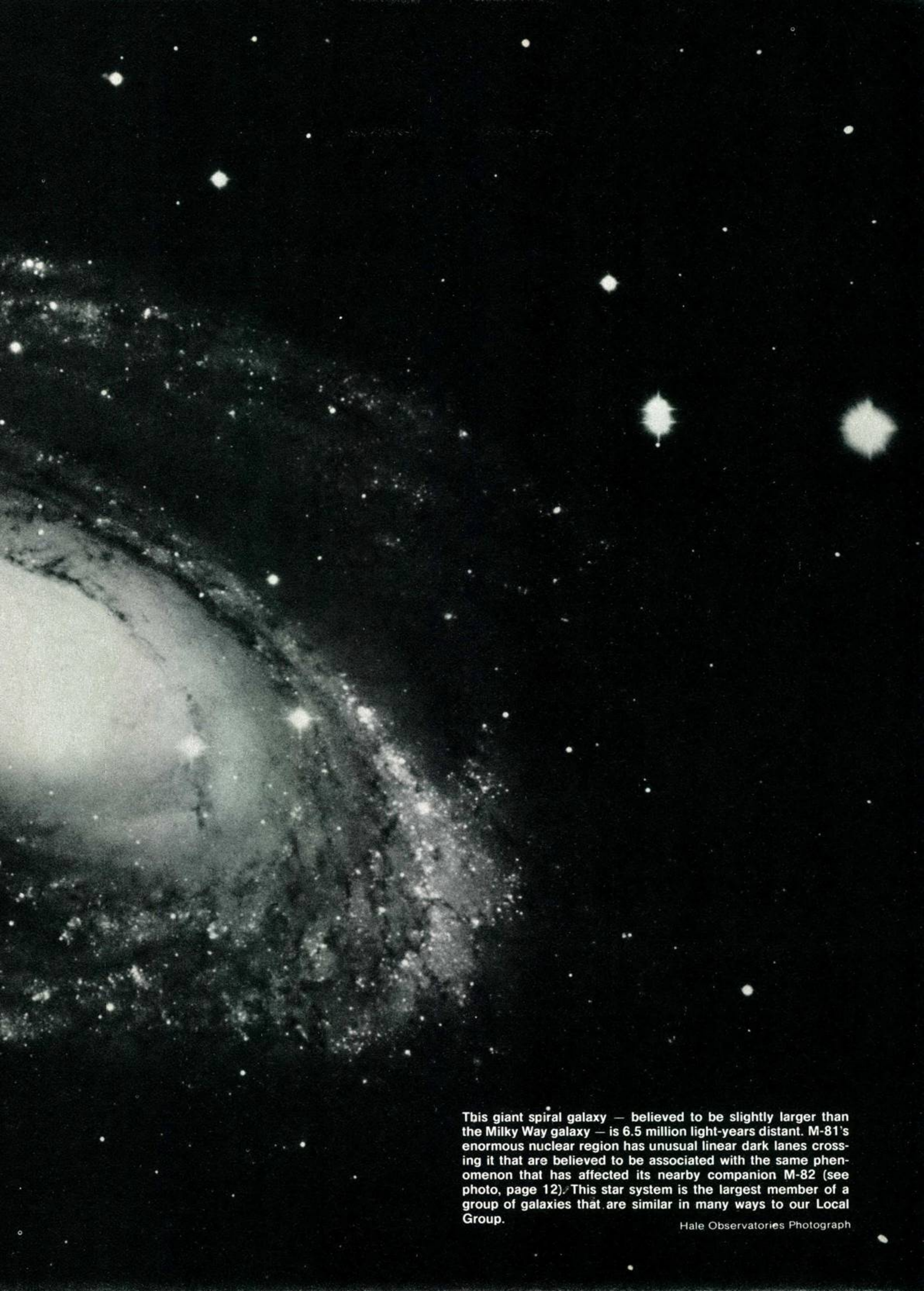
Theoretical calculations show that in a flattened rotating galaxy, any gas or dust should be concentrated into spiral arms, trailing behind the general rotation of the galaxy — something like the arms of a 4th of July pinwheel. Theory also predicts that new young stars should continually form from that interstellar material. A rare few of those new stars should be of exceptional luminosity (like Rigel and Deneb). These few highly luminous stars outshine most other stars in a spiral galaxy making the spiral arms, where star formation occurs, stand out conspicuously. Thus, spirals are galaxies where interstellar matter is present in large amounts and where substantial star formation is now taking place — the reverse of the situation we noted in the ellipticals.

Spiral galaxies are not all alike. In some, the arms are tightly wound and are comparatively smooth. In these spiral galaxies, the nuclear bulges tend to be relatively large. At the other extreme are spirals with little or no central bulge, but have wide open arms which have many conspicuous conden-

The Local Group of Galaxies

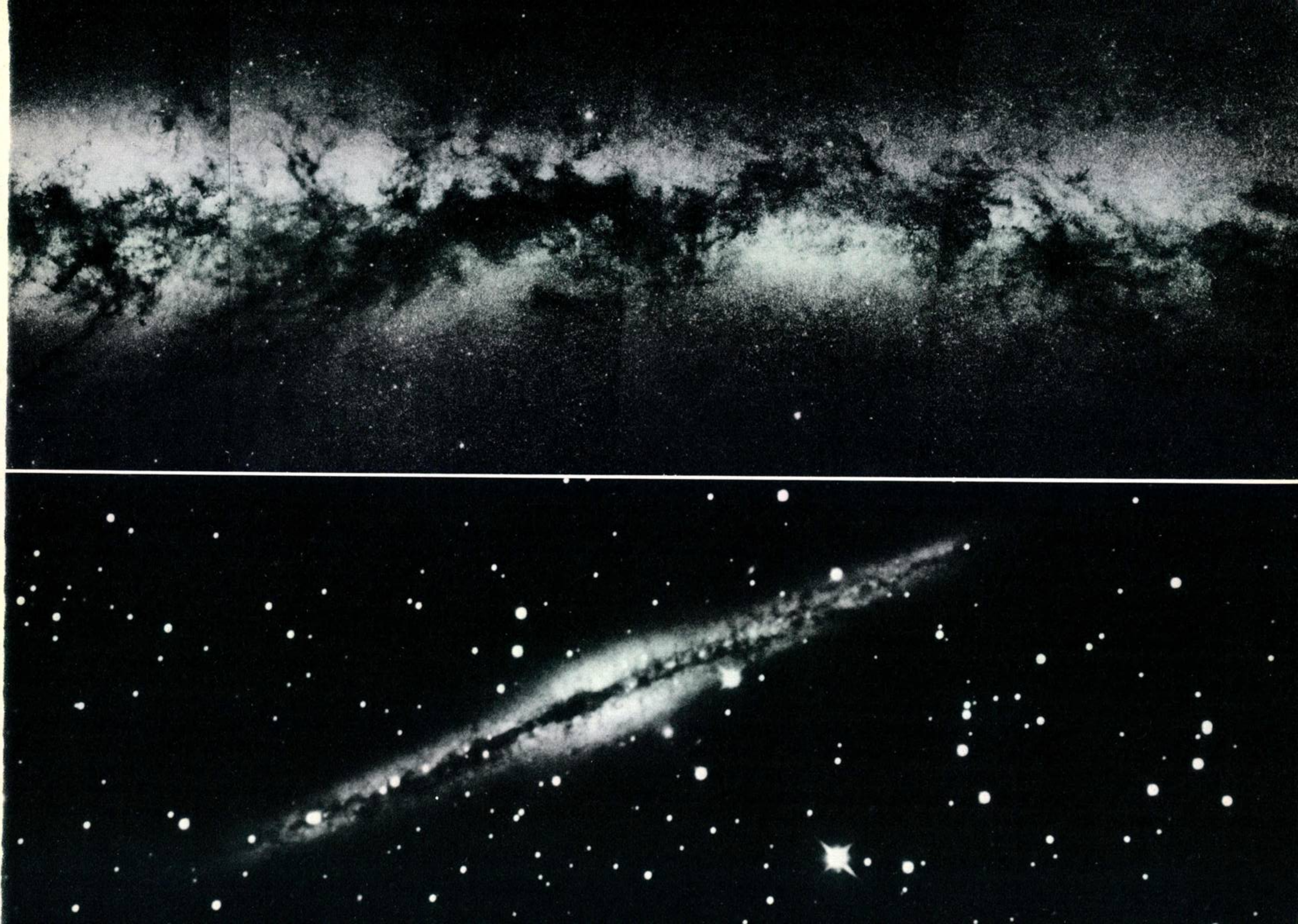
Galaxy	Type	Visual Magnitude	Distance (1,000 light-years)	Diameter (1,000 light-years)	Approximate Luminosity (million suns)	Approximate Mass (million suns)
Milky Way	Sb	---	---	100	7,600?	200,000
Large Magellanic Cloud	Irregular	0.1	160	30	2,000	6,000
Small Magellanic Cloud	Irregular	2.3	195	25	400	1,500?
Ursa Minor System	E4 (dwarf)	10?	230	3	0.25	0.25?
Sculptor System	E3 (dwarf)	8.0	260	7	4	3?
Draco System	E2 (dwarf)	11.5?	330	5	0.2	0.2?
Fornax System	E3 (dwarf)	8.4	600	10	20	20?
Leo II System	E0 (dwarf)	12.0	620	4	0.4	1?
Leo I System	E4 (dwarf)	12.0	1,300	7	2	2?
NGC-6822	Irregular	8.9	1,500	9	150	1,500?
NGC-147	E6	9.7	1,950	10	70	350?
NGC-185	E2	9.4	1,950	8	90	450?
NGC-205	E5	8.2	2,250	16	275	1,500?
NGC-221 (M-32)	E3	8.2	2,250	8	275	1,500?
Andromeda Galaxy (M-31)	Sb	3.5	2,250	130	21,000	300,000
Andromeda I	E0 (dwarf)	14?	2,250?	1.6?	2?	2?
Andromeda II	E0 (dwarf)	14?	2,250?	2.3?	2?	2?
Andromeda III	E3 (dwarf)	15?	2,250?	2.9?	2?	2?
NGC-598 (M-33)	Sc	5.8	2,250	50	3,000	8,000
IC 1613	Irregular	9.6	2,400	18	60	400?

The table lists those galaxies that are generally agreed to belong to the Local Group. Particularly uncertain quantities are followed by question marks.



This giant spiral galaxy — believed to be slightly larger than the Milky Way galaxy — is 6.5 million light-years distant. M-81's enormous nuclear region has unusual linear dark lanes crossing it that are believed to be associated with the same phenomenon that has affected its nearby companion M-82 (see photo, page 12). This star system is the largest member of a group of galaxies that are similar in many ways to our Local Group.

Hale Observatories Photograph



sations of glowing nebulae and star clusters, and which display a less "tidy" appearance than the tightly wound spirals. Hubble subclassified spirals into a sequence — *Sa*, *Sb*, and *Sc* — according to the relative tightness of the spiral arms and the conspicuousness of the central bulge. These properties are most pronounced in the type *Sa*.

In perhaps a third of the spiral galaxies, the arms begin from the ends of straight "bars" of stars and interstellar matter (see photo, page 23). Evidently, in these *barred spirals* (which Hubble classed *SB*), the inner parts (which include the bar) all rotate with the same angular velocity — as in a solid body — so that the outer regions of the bars do not trail behind.

In all spirals there is accumulating evidence that there may be a sparse but vast surrounding corona of stars — spread more or less throughout a spherical region about each galaxy — which contributes substantially to the total number of stars in the system. In fact, in some respects spirals resemble large diffuse ellipticals with superimposed disks and spiral arms.

Origin and Evolution of Galaxies

Some early investigators suggested that galaxies were formed as ellipticals and slowly evolved through a sequence of spiral forms. Even now, we sometimes still refer to elliptical and spiral galaxies as "early" and "late", respectively, in keeping with these old ideas.

Today, however, we know that those early evolutionary ideas cannot be correct. Yet stars do evolve as they age and expend their supply of nuclear fuel. How does this evolution of stars within a galaxy relate to the evolution of the galaxy itself?

At present, we have relatively little direct observational evidence concerning the evolution of galaxies. Still, we presume that they do, in fact, change as the stars within them age. For example, we expect elliptical galaxies (where star formation does not occur on a large scale) to become gradually redder and less luminous as the stars within them grow older.

The evolution of a galaxy is not, however, thought to determine whether it is an elliptical or a spiral. We think that this distinction depends on the initial rotation of the cloud of material that formed the galaxy. Those protogalaxies of substantial initial rotation would have to have sped up their spins as they contracted to conserve their angular momentums; as a result they flattened, rather like a spinning pizza. Thus the spirals are believed to be galaxies whose initial matter had higher than average angular momentum for their masses, while the elliptical galaxies are thought to be those whose protogalaxian clouds of material had lower rotation.

THE BRIGHTEST GALAXIES

Name	Type	Visual magnitude	Distance (light-years)
LMC*	Irregular	1**	160,000
SMC	Irregular	2**	195,000
M-31*	Sb	5	2,250,000
M-33*	Sc	6	2,250,000
M-81*	Sb	7	6,500,000
M-83*	Sc	7	8,000,000
NGC-55	Sc	7	7,500,000
NGC-5128	E0 ?	7	not available
M-94	Sb	8	12,000,000
M-101*	Sc	8	14,000,000
M-51*	Sc	8	12,000,000
M-49	E4	8	37,000,000
NGC-4258	Sb	8	14,000,000
M-104*	Sb	8	37,000,000
M-32*	E2	8	2,250,000
M-63	Sb	9	14,000,000
M-82*	Irregular	9	6,500,000
M-64	Sb?	9	12,000,000

* A photograph of this galaxy is in this article.

** Although it is possible to give exact visual magnitudes for the Large and Small Magellanic Clouds, such values are of little practical use since these objects are spread over relatively large areas of the sky and appear to the eye much fainter than the magnitudes given.

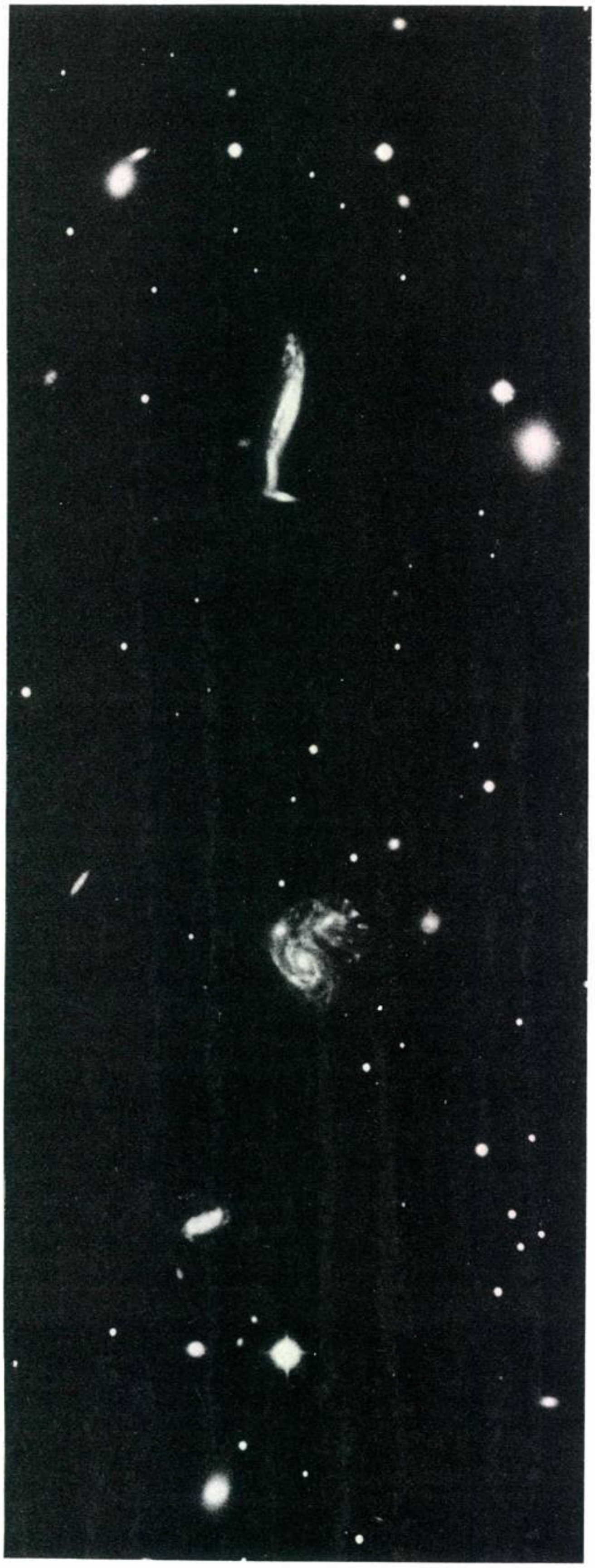
Peculiar Galaxies

Some galaxies are unusual in their properties. Notable among these are the *Seyfert galaxies*, named for the late astronomer Carl Seyfert who first described them. There are now a few dozen of these galaxies known. They are spirals whose nuclei emit energy at certain infrared wavelengths with unusual intensity. Possibly related to Seyfert galaxies are *N galaxies* — elliptical galaxies with small but unusually luminous nuclei. It is as if in the central parts of Seyfert and N galaxies there are processes operating that cause the emission of energy of extreme intensity. Even in the nucleus of our own galaxy, there are strange unexplained strong sources of energy — but on a much smaller scale than in Syefert galaxies. Most extreme in this category may be the *quasars*.

Quasars appear as points of light and are usually sources of radio waves that look like stars on ordinary photographs. However, their spectra show very large Doppler shifts, as would galaxies of extremely great

From inside our own galaxy (left) we can see the dense swarms of stars and clouds of dust that form a narrow band in the sky called the Milky Way. The same ribbon of stars and obscuring dust can be seen when we look at other galaxies edge-on (such as NGC-891, right). To examine the universe beyond the Milky Way — the realm of the galaxies — earthly telescopes must be directed away from the heavily populated plane of our galaxy. If we inhabited a planet of a sun in an elliptical galaxy we might not be able to look out the "top" and "bottom" of our galaxy. We would then be unaware of the millions of other galaxies beyond our own.

Hale Observatories Photographs



Hale Observatories Photograph

Galaxies are born in clusters and seem to remain in bunches due to the effects of their mutual gravitational attractions. Some galaxy clusters are small (like the Local Group), and some, as seen here, are impressive swarms of galaxies of all types. This is the heart of the Hercules cluster of galaxies which is over 500 million light-years distant and consists of many hundreds of galaxies.

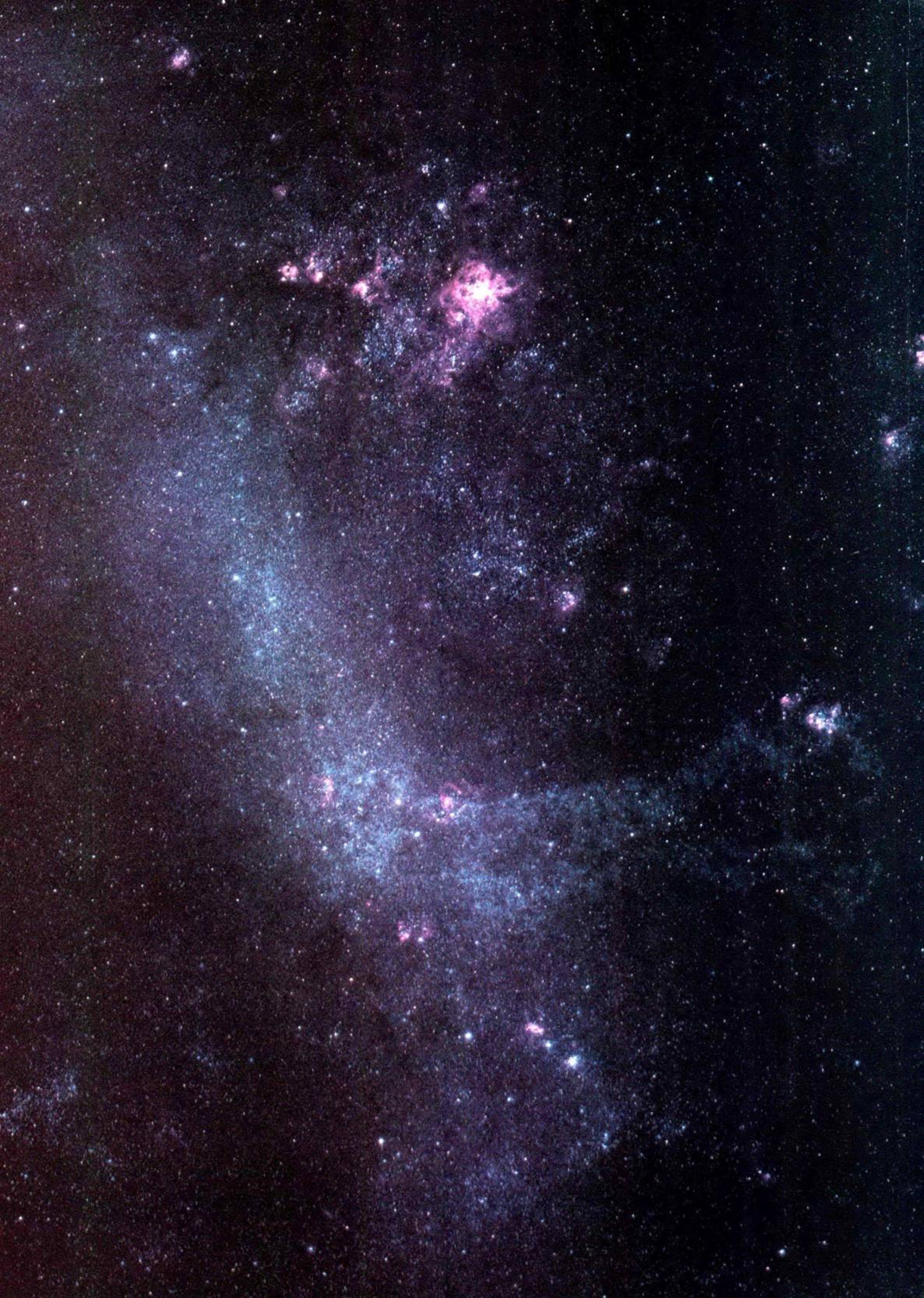
distances — up to 10 billion light-years. Most astronomers lean to the hypothesis that quasars are either peculiar galaxies or the abnormally brilliant nuclear regions of galaxies that are otherwise too faint and/or too distant to be seen. There is speculation that the unusual properties of quasars, N galaxies, Seyfert galaxies, and possibly even the nucleus of our own galaxy, result from similar kinds of violent events occurring in the nuclei of otherwise normal galaxies. Perhaps all galaxies can display these properties at some time or other in their existence.

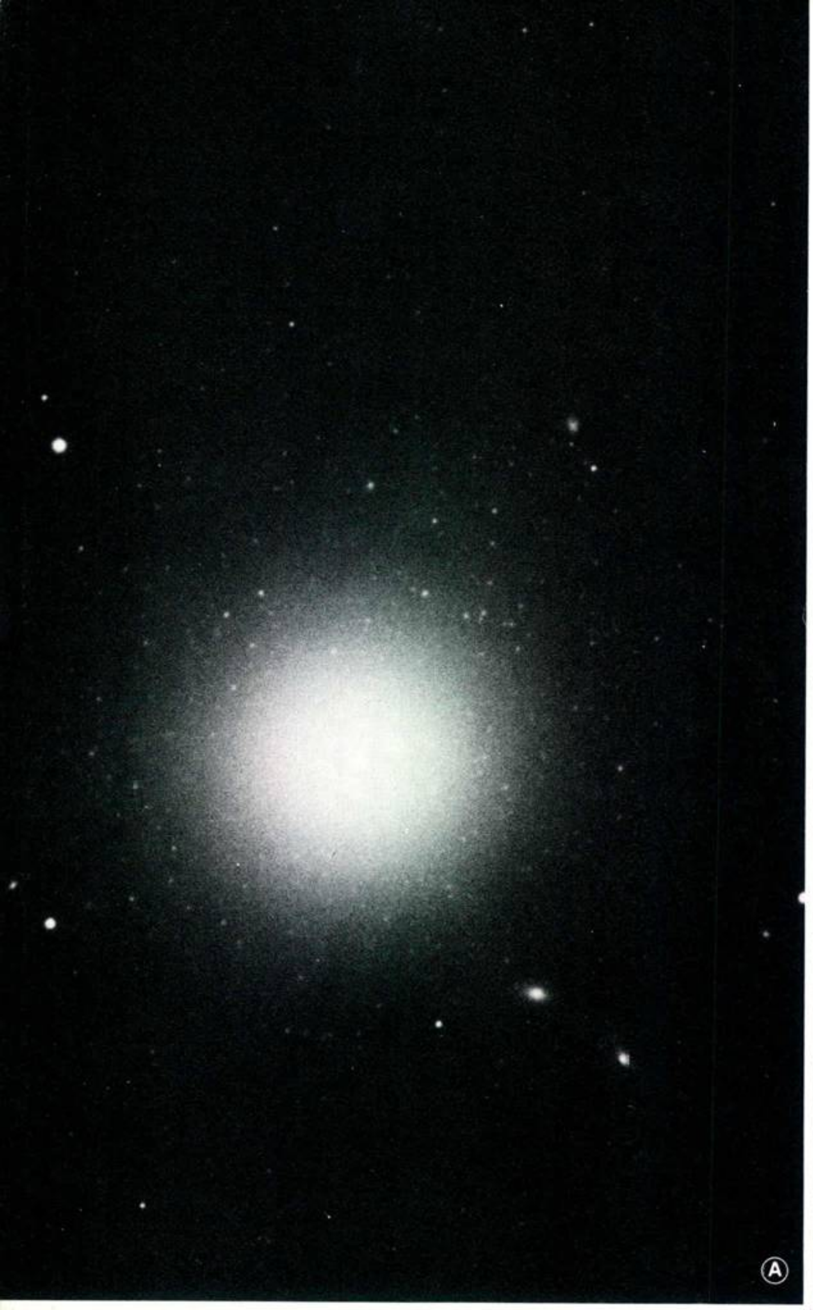
Just as all stars emit all wavelengths of electromagnetic energy (gamma rays, X-rays, ultraviolet radiation, light, infrared radiation and radio waves), so normal galaxies should emit all kinds of radiation. However, remote galaxies would be expected to be observable only in visible light. Even for the nearest galaxies, only the light from their stars and the radio radiation from the interstellar clouds within their spiral arms should be detected from Earth with appreciable strength.

Yet there are galaxies that emit energy with unexpected intensity at certain wavelengths. Some Seyfert galaxies, for example, emit infrared radiation in amounts exceeding their visible radiation by 100 times! Also, a large number of galaxies emit radio waves in incredible intensity; these are known as *peculiar radio galaxies.*

Most peculiar radio galaxies are giant ellipticals. Sometimes the radiation can be associated with an unusual feature in the optical image of the galaxy. In the galaxy M-87 in the Virgo cluster, for example, the feature is a jet of gas extending away from its central nucleus. More often, a peculiar radio galaxy appears on photographs as a normal giant elliptical. Its radio emission, however, generally comes from two symmetrical regions on either side of the galaxy, separated from it by hundreds of thousands of light-years. The nature of the radio radiation indicates that it comes from charged particles (electrons) spiraling around the lines of force of an extensive magnetic field (it is called *synchrotron radiation*). The source of the very great energy required for the magnetic fields, as well as of the ionized gas needed to account for the electrons, is — as of now — still unexplained. Most quasars, similarly, are straddled by pairs of radio sources requiring great amounts of energy.

The nearest galaxy beyond the Milky Way is only 160,000 light-years distant — barely outside the fringe of our galaxy. Known as the Large Magellanic Cloud (LMC), this sprawling irregularly shaped swarm of about six billion stars is laced with clouds of cosmic dust and gas — some of which is condensing to form new stars. Because this is our nearest galaxy neighbor, the individual stars in it are easier to study than those in more distant stellar assemblages. The LMC is about 30,000 light-years across in its longest dimension. The 60 inch Schmidt telescope was used for this remarkable celestial portrait — the best color photo of the LMC ever obtained. Cerro Tololo Inter-American Observatory Photograph





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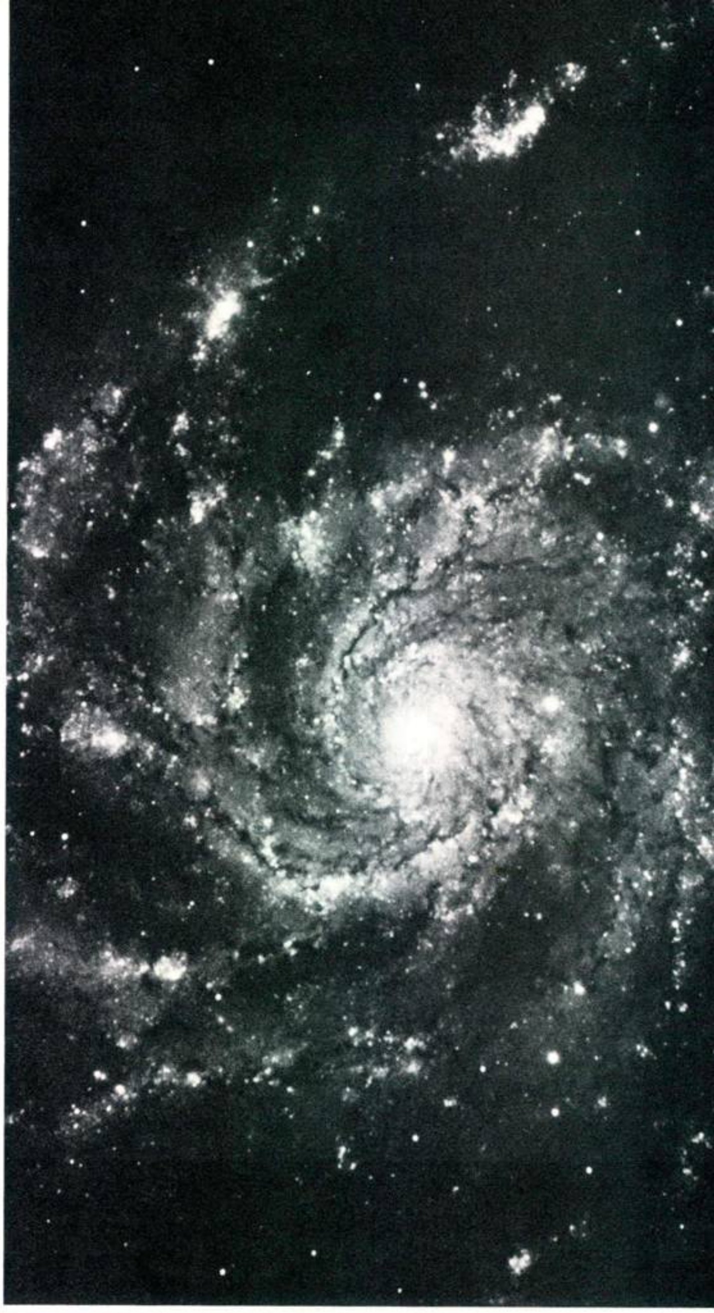

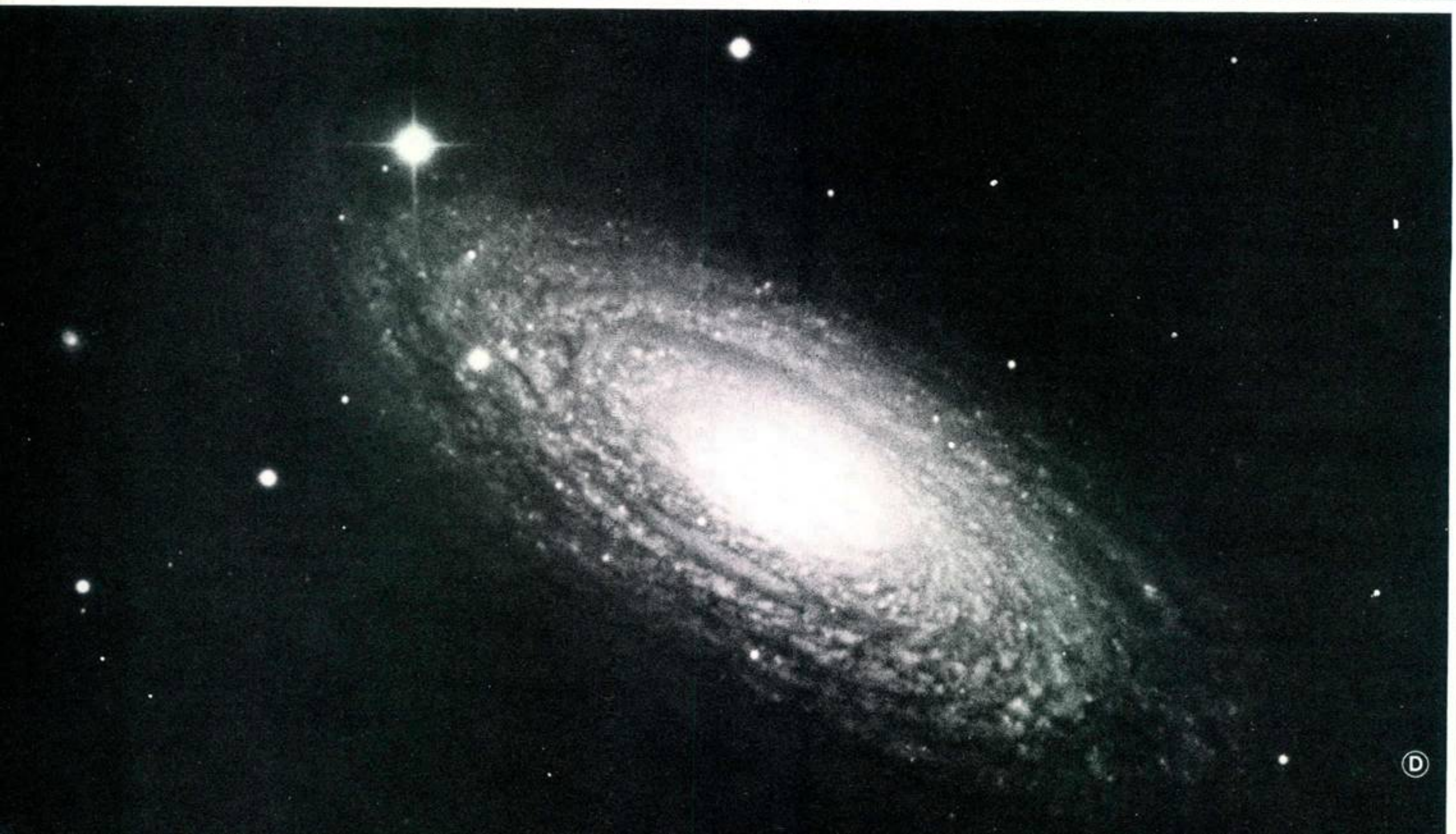

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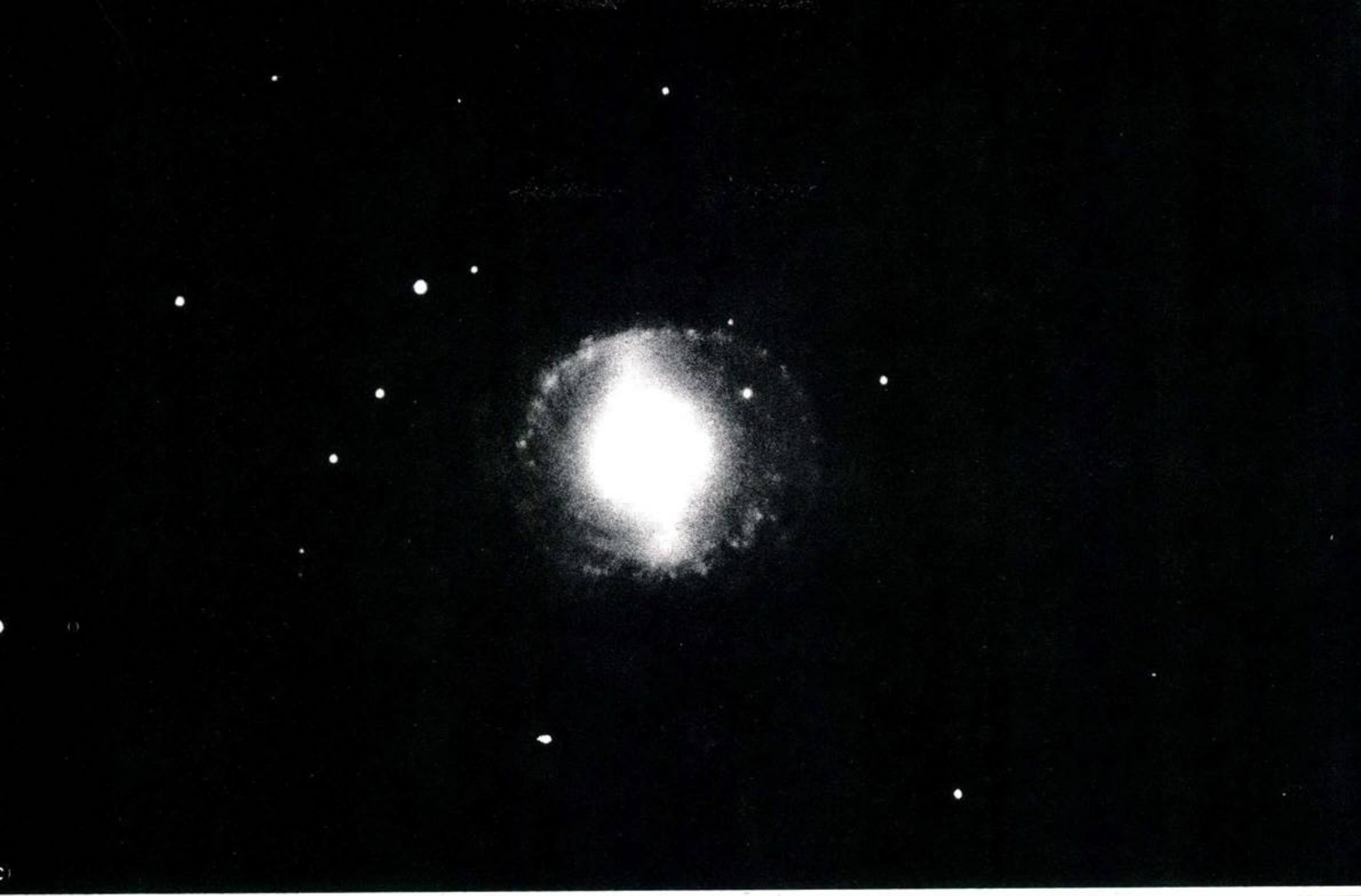

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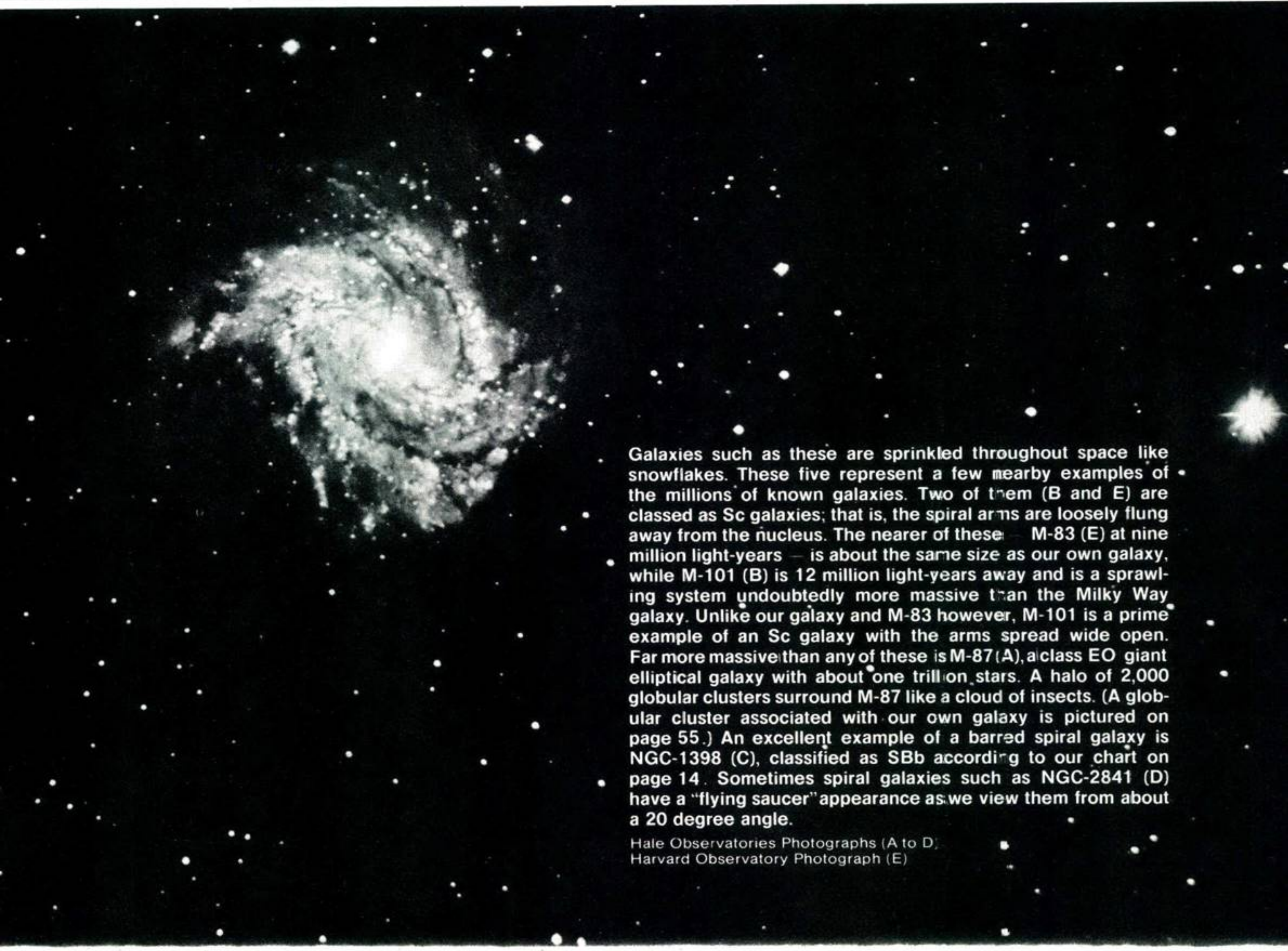


Galaxies such as these are sprinkled throughout space like snowflakes. These five represent a few nearby examples of the millions of known galaxies. Two of them (B and E) are classed as Sc galaxies; that is, the spiral arms are loosely flung away from the nucleus. The nearer of these — M-83 (E) at nine million light-years — is about the same size as our own galaxy, while M-101 (B) is 12 million light-years away and is a sprawling system undoubtedly more massive than the Milky Way galaxy. Unlike our galaxy and M-83 however, M-101 is a prime example of an Sc galaxy with the arms spread wide open. Far more massive than any of these is M-87 (A), a class EO giant elliptical galaxy with about one trillion stars. A halo of 2,000 globular clusters surround M-87 like a cloud of insects. (A globular cluster associated with our own galaxy is pictured on page 55.) An excellent example of a barred spiral galaxy is NGC-1398 (C), classified as SBb according to our chart on page 14. Sometimes spiral galaxies such as NGC-2841 (D) have a "flying saucer" appearance as we view them from about a 20 degree angle.

Hale Observatories Photographs (A to D)
Harvard Observatory Photograph (E)

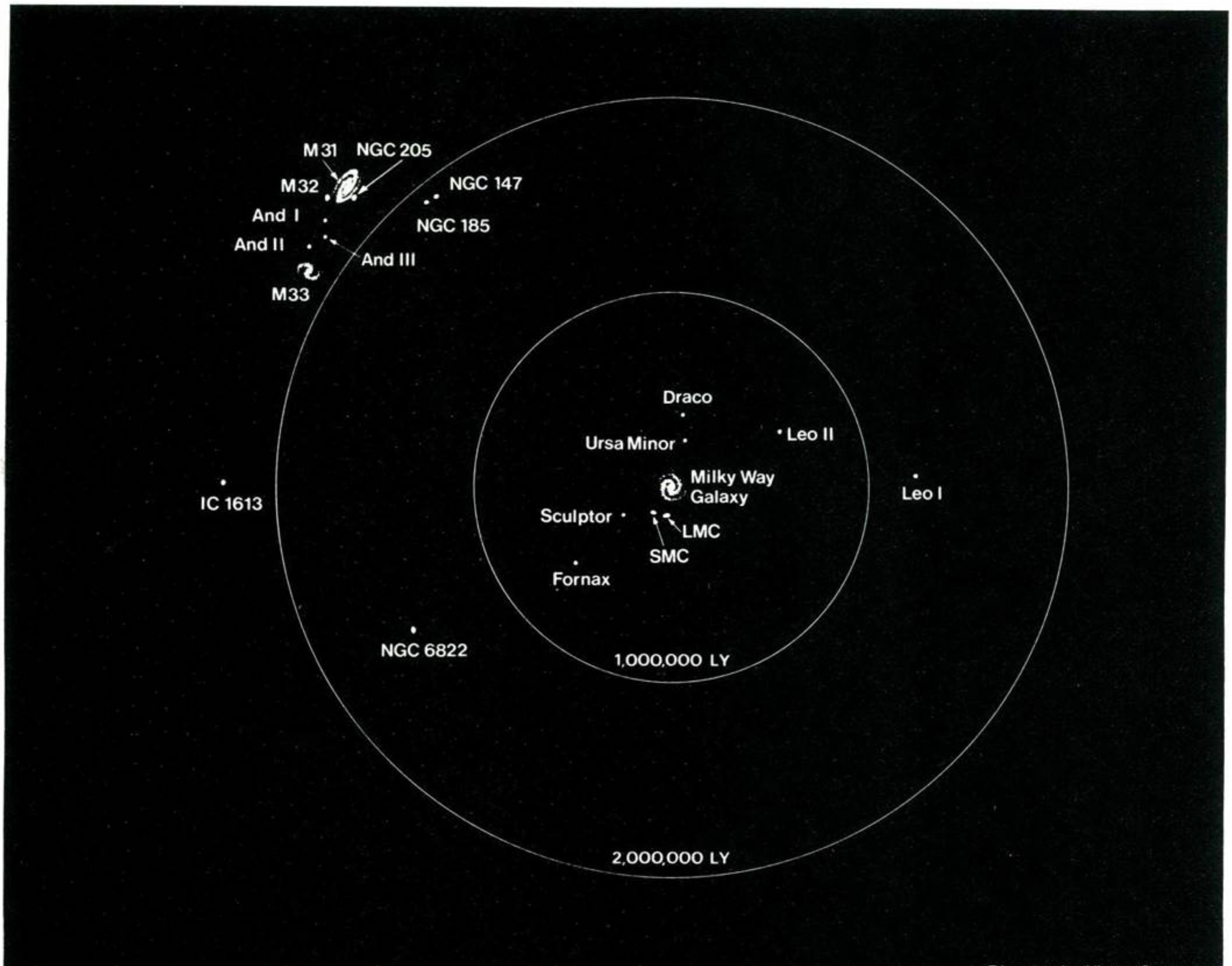


Diagram by Victor Costanzo

Two major galaxies – Andromeda and the Milky Way – and 18 smaller assemblages of stars, make up the Local Group of galaxies. Statistics on the individual members are tabulated on page 15. All these galaxies are believed to be gravitationally bound into a family unit. Other clusters of galaxies range from groups like this to swarms with thousands of members.

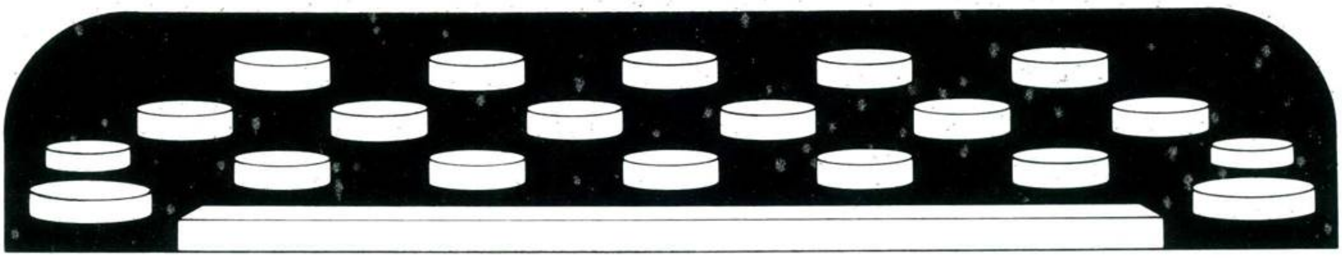
The Universe of Galaxies

The part of the universe than can be explored contains at least one billion observable galaxies, and probably many times this number of dwarf galaxies like those in the Local Group. In this universe of galaxies we find some patterns and consistency. But we also find mysterious sources of radio and infrared radiation, and evidence for magnetic fields and ionized gas — some of which is at very high temperatures. We find objects such as quasars and other peculiar galaxies that vary in light in unexplained manners. We find vast clusters of galaxies whose members seem to move too fast to be contained by the gravitational fields of the clusters, and yet which do not seem to escape from the clusters. We find X-rays that may be coming from the space between the galaxies, in which case their origin is a complete mystery. Even some cosmic rays (atomic nuclei striking the upper atmosphere of Earth) may be coming from intergalactic space; but how and why we do not know.

In short, the universe beyond the Milky Way is a treasure house of mysteries — each a nugget worth far more than its "weight in gold" as a subject for study. The true excitement of exploration in the realm of the galaxies far exceeds that of the artificial mysteries of fiction and pseudoscience.

Less than 200 years ago, William Herschel — observing with the first large reflecting telescope — speculated to his sister Caroline, at the foot of the observing ladder, that he had observed thousands of "universes" that night. What would he think if he could be here today?

Dr. George O. Abell, professor and chairman of the department of astronomy at the University of California — Los Angeles, is internationally known for his research on clusters of galaxies and the large scale distribution of matter in the universe. The third edition of his widely used text, **Exploration of the Universe**, *is to be released in a few months. He is a frequent contributor to both popular and professional astronomy journals.*



IN FOCUS

Sir / Your Astro-News article, "Mysterious Glow Above Saturn's Rings" (July 1974), suggested that there have been no previous indications of a fourth ring of Saturn. It also gave the misleading opinion that for additional evidence, we must await either the next occultation or the Pioneer 11 flyby of Saturn in 1979.

As early as 1900, several visual observers had reported a faint exterior ring, which became known as the D ring. Disbelief in it spread after E. E. Barnard failed to see it with the 40 inch Yerkes refractor in 1909.

Allegheny Observatory photographs of Saturn, taken in late 1966 with the 30 inch Thaw refractor, indicate the presence of an extremely faint ring beyond the familiar A, B, and C rings, according to Walter A. Feibelman of the University of Pittsburgh (see **Nature**, May 20, 1967). All long exposure plates taken between Oct. 27 and Dec. 12, while the ring system was nearly edge-on, show a thin line forming a continuation of the rings to more than twice their recognized extent. Microphotometric tracings of the original negatives confirm this delicate feature.

In addition to the obvious need for more observations, Feibelman urges a careful re-examination of existing plates taken with other telescopes near times of edge-on ring orientation (which occurs every 15 years). Photographs taken with large reflectors having their secondary mirror supports at an angle to the east-west, north-south direction are particularly valuable — since their diffraction-crosses on long exposure plates would not mask the thin line.

JOHN HEWITT
Berkeley, Calif.

Dear Mr. Hewitt / You are quite correct in suggesting that the fourth (outer) ring of Saturn is fairly well accepted as a real phenomenon. Our report failed to mention that the glow was observed above the globe of Saturn. We recently spoke to the observers involved in that event, and they told us that the disk of Saturn emerged from occultation before the rings. They feel that the glow probably was mostly associated with the planet itself. On this point our report was in error.

Letters intended for this column should be addressed to The Editors of ASTRONOMY. We are sorry but the volume of mail does not permit individual replies.

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Saturn—the New Frontier

by
William K. Hartmann

Each new probe of the outer solar system — whether by spacecraft or Earth based observation — leads us to more striking visions of distant places. Now that a spacecraft has flown by Jupiter revealing unexpectedly intense magnetic fields, a satellite with a hydrogen tail, and (perhaps) a 15,000 mile deep ocean of liquid hydrogen, the frontier in the solar system has moved out to Saturn.

While a Saturn spacecraft is on the drawing boards, astronomical observations and theoretical interpretations of Saturn and its satellites are being made at a greater rate than ever. The satellite system alone provides more than its share of intriguing discoveries and mysteries — including the strange Iapetus with one face six times as bright as the other, and cloud-shrouded Titan where conditions in hypothetical, volcanically heated ponds might resemble conditions on the primeval Earth.

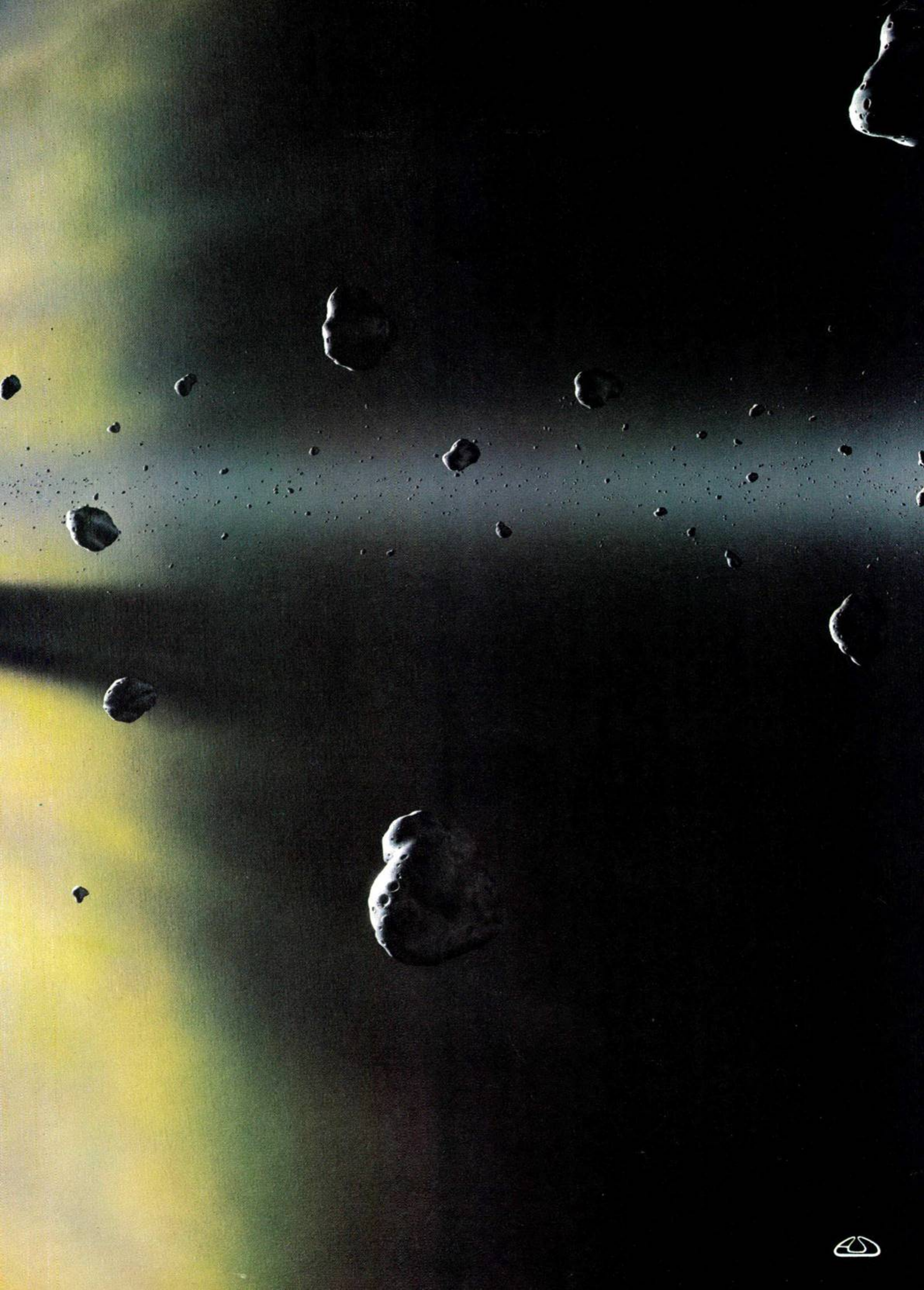
Here we will confine ourselves to Saturn itself and its rings, where dozens of questions are yet to be answered: What is Saturn made of? What is its internal structure? What are the rings made of? How big are the particles in the rings? Why are there gaps in the rings? Why do the rings exist at all?

First, the atmosphere. Tracking of rare, prominent clouds in the Saturnian atmosphere reveals a rotation period of 10 hours 14 minutes near the equator, and longer periods — such as 10 hours 40 minutes — at higher latitudes. The rotation rate, only 20 minutes longer than Jupiter's is sufficient to bulge the equator and squash the poles of Saturn resulting in a noticeably oblate shape. (The polar diameter is 66,900 miles while the equatorial diameter is 74,150 miles.)

These bits of information provide clues about the internal structure of Saturn, since the shape of

Sailing around Saturn at speeds up to 90,000 m.p.h., the snowballs that make up the planet's spectacular ring system are believed to vary in size from dust to boulder size. This rendering is a hypothetical view from "inside" the rings at a point near their inner edge where the ring particles are relatively scarce. This inner (or crepe) *ring is nearly transparent as* seen in the illustrations on the following pages and the cover photo. Saturn's yellow cloud decks loom at the left.

Artwork by Adolf Schaller



a planet depends on its rotation rate and internal mass distribution. (Earth, which is made of "stiff" material and rotates more slowly, deviates far less from a spherical shape than Saturn.) Other clues to internal structure come from the motions of the satellites, which are affected by the symmetry or asymmetry of the planet's gravitational field, produced in turn by the mass distribution inside Saturn.

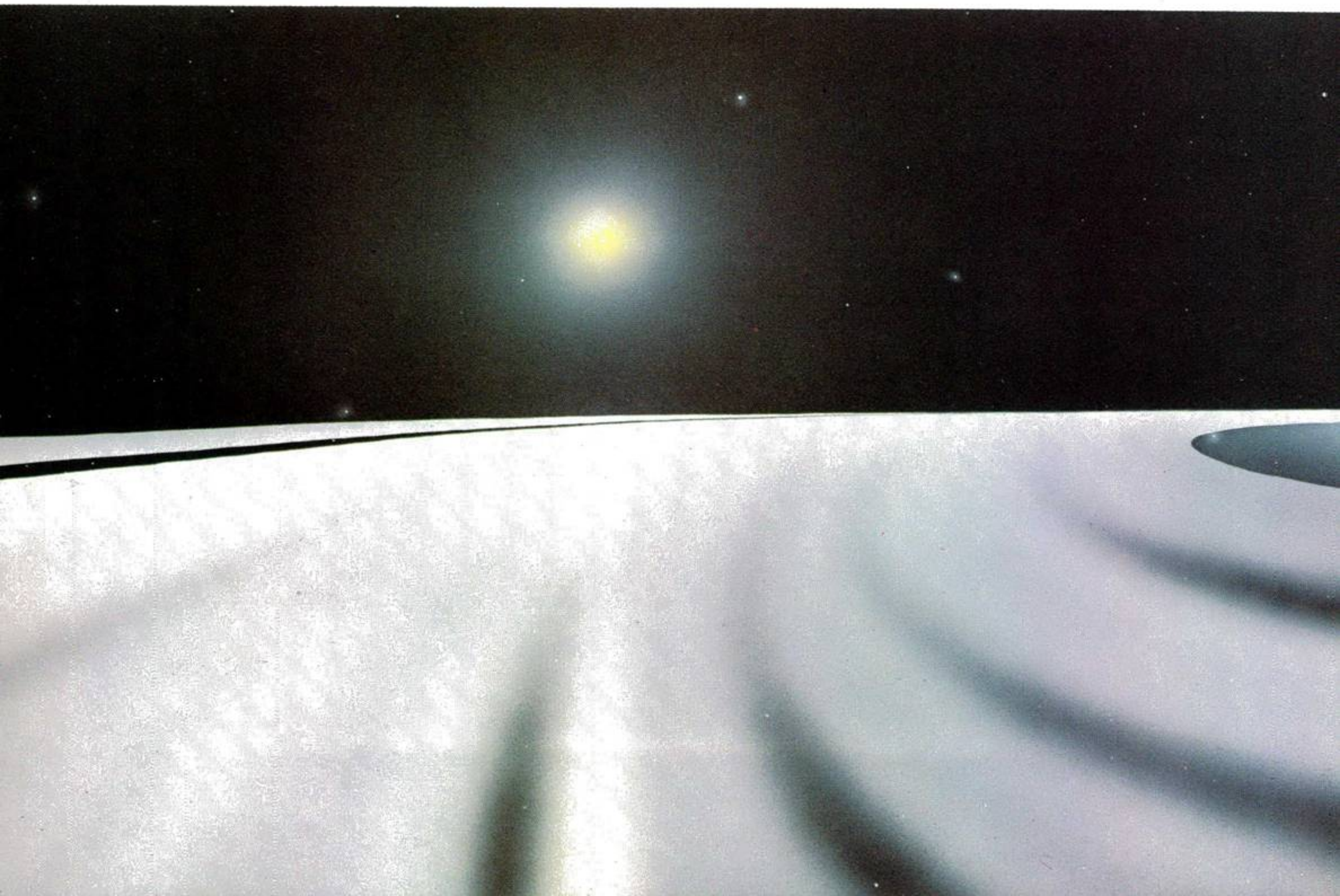
With these data in hand, astronomers have deduced that Saturn is obviously composed of much less substantial material than Earth is. In fact, on the average, the stuff Saturn is made of is only 70 percent as dense as water. To put it another way, if we could provide a big enough ocean, Saturn would float on it. This indicates that Saturn must be mainly made up of the light, cosmically abundant gases — hydrogen and helium.

This has been confirmed in part by direct spectroscopic detection of hydrogen as well as methane (composed of carbon and hydrogen) and possibly ammonia (nitrogen and hydrogen). Some water and more complex molecules may be present as well. This is not a very pleasant atmosphere by human standards — but as Cornell University exobiologist Carl Sagan is fond of pointing out, such an atmosphere has the potential of forming very complex organic molecules that could form the building blocks of living organisms. Sagan has suggested the remote chance of small life forms (or protolife forms) floating in the warm lower atmosphere of Jupiter. Such a possibility, although even more remote on Saturn,is an intriguing speculation.

What would we see of this atmosphere from close-up? Recent descriptions of the visible atmosphere by W. Macy of the University of Texas invoke a high clear layer, a lower dusty layer, and finally the visible clouds — probably of ammonia — blocking any further view into the deeper layers. (This description may be compared with the account of Jupiter's atmosphere in the November 1974 issue.)

And beneath the clouds? Here we must return to a more detailed analysis of the dynamical and chemical clues described above. A conservative approach is to use only the directly determined dynamical numbers, without speculating on the composition. These numbers allow estimates of average values of interior densities, pressures, etc. University of Arizona astrophysicist William Hubbard has provided us with some new calculations recently submitted to the **Astrophysical Journal.** These calculations indicate a central region inside Saturn where densities reach about three times that of water, with a drop to densities less than half that value in the outer half of the planet. Various hydrogen-rich ices, such as frozen methane and ammonia, might produce such a planet.

A panoramic view from just above Saturn's rings — one of the most awesome vistas known to man — is depicted in this artist's rendition. Artwork by Adolf Schaller



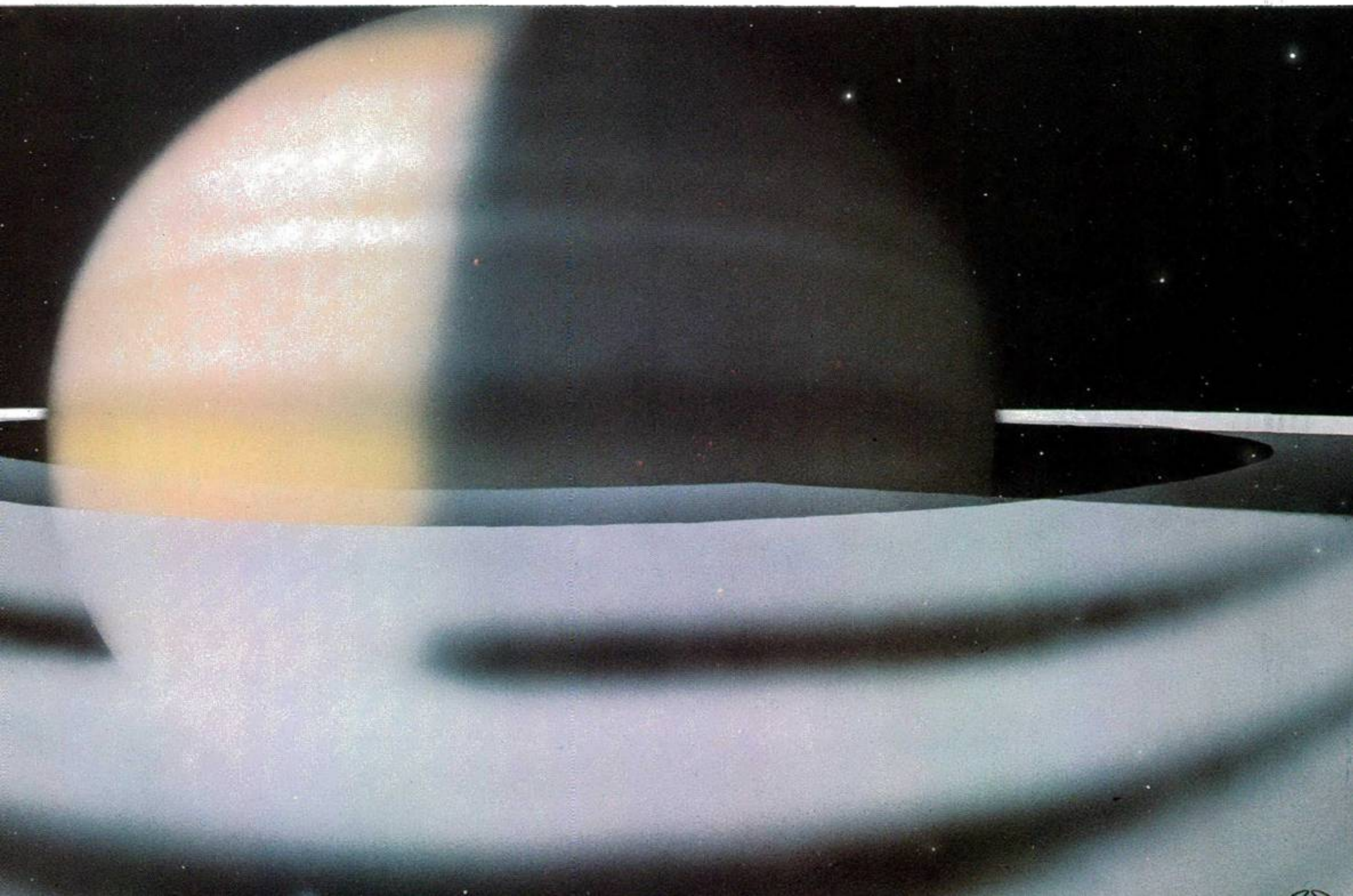
On the other hand, New York astrophysicists M. Podolak and A. G. W. Cameron have taken a more speculative approach in calculations published in **Icarus** in 1974. They made various assumptions about the chemical composition of Saturn — assuming for example that the hydrogen/helium ratio is the same as that in the sun, and that different chemicals condensed in certain sequences during the initial formation of the solar system. The last assumption leads to a layered structure for the planets. According to these models, Saturn has a distinct rocky core containing about 20 times Earth's mass, and possibly reaching densities as high as 22 times the density of water. In some interpretations the core is assumed to be surrounded by an icy or slushy layer of water, ammonia, and methane. However most of the planet's volume is occupied by outer layers of metallic hydrogen (something like Jupiter's interior) and an outermost layer composed mostly of hydrogen — much of which is gaseous and comprises the atmosphere.

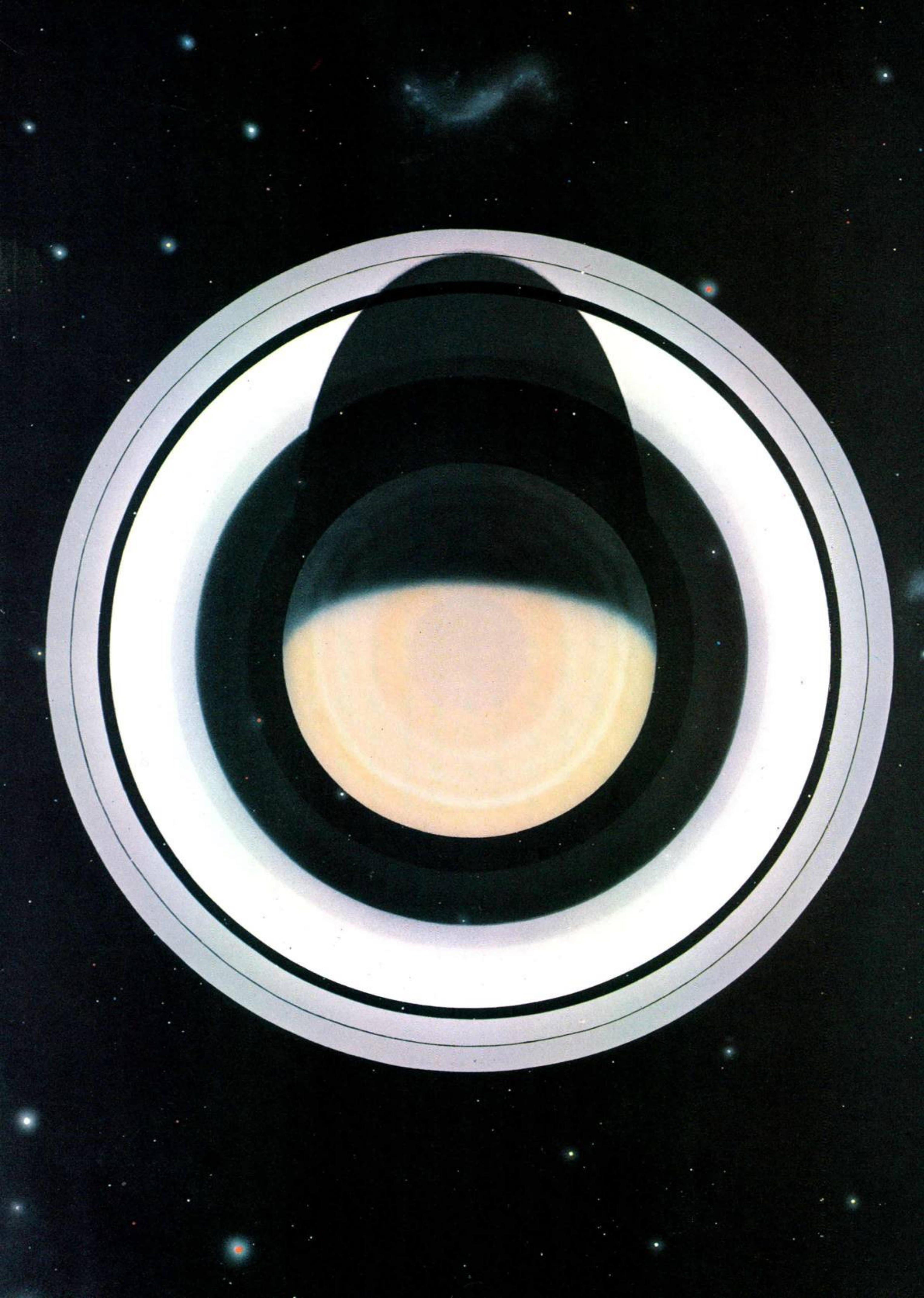
While Saturn models by various researchers are reasonably consistent in the outer layers, there are gross differences in theories of the inner quarter radius, with estimated densities differing by a factor of 10. Hubbard points out that recently improved dynamical data can be applied to the models of Podolak and Cameron. Clearly, we are still groping uncertainly for knowledge of the structure of Saturn. Meanwhile Pioneer 10's flight by Jupiter gave new dynamical data that suggested a denser core and greater importance of liquid metallic hydrogen than had been anticipated. Hubbard has commented that while Pioneer 10 did not directly resolve problems of Saturn, it did at least give credence to certain observers' pre-Pioneer estimates of the giant planet's dynamical data.

If it were not for the rings, all of this would amount to an interesting planet that lets us extend our theories and understanding of Jupiter. But without the rings, Saturn would be a plain cousin to the massive, chaotic Jupiter.

Without a doubt, the rings are extraordinary. Consider just one of their characteristics — their thinness. Although they are at least 170,000 miles in diameter, they are so thin that they virtually disappear when seen edgewise from Earth; French astronomers estimated in 1969 that they are no more than 1.7 miles thick. This means that if we sent a flyby spacecraft to make measurements of the rings we would face a very difficult problem. If the spacecraft tried to skim along the plane of the rings, it would likely hit something. And if it tried to pass vertically through the ring plane, the whole encounter would be over in a few hundredths of a second!

When Galileo first looked at Saturn through his crude telescope in 1610, he could see an extended object unlike the round planets Mars and Jupiter; he called it a triple planet. It took until the 1660s





to determine that it was a round planet surrounded by a flat ring.

What exactly is the ring system? In 1859, a 28 year old English scientist, James Clerk Maxwell, published a dynamical study showing that a flat solid ring would be unstable and that the ring must be composed of a myriad of small particles. The study won Maxwell a prize and established him as a leading physicist. Like a first-chair cornet player moving to first-chair violin, Maxwell went on to make the brilliant theoretical discovery of the wave nature of light and other electromagnetic radiation.

Maxwell's theory of the rings was confirmed in 1895 when American astronomer James Keeler observed spectroscopically the different revolution rates of various parts of the rings with the innermost region revolving fastest. It was obvious that the rings could not be solid and must be millions of tiny, individual "moonlets".

This discovery opened nearly a century of debate about the nature of the particles that make up the rings. Estimates have ranged from microscopic dust to kilometer sized planetoids! The last decade's observations have brought astronomers to more consistent descriptions. Photometric, radar, and other data have led most analysts to talk of fist sized particles averaging a few inches in diameter. Spectrophotometric observations indicate that they are composed of (or at least covered by) frozen water. The radar observations show that when the ring particles are illuminated, they reflect an unusually great amount of light back toward the source of illumination. In this "backscattering", at some wavelengths they may be at least half as efficient as Scotchguard tape! This is interpreted to mean that the surfaces of the particles are quite rough.

Thus, a visitor to the rings might find himself surrounded by a swarm of floating, scattered ice-balls resembling very large, rough hailstones.

The reason that "rings" is plural and not singular is that gaps and brightness differences define distinct rings. The most famous gap, called Cassini's division, was discovered in 1675 and is visible in a small telescope of a few inches aperture. In 1969 the French observer Guerin announced discovery of a new, very faint ring, extending out from the planet but separated from the brighter rings by a large gap.

It is easy to imagine how collisions and other disturbances could send ring particles shooting into the gaps, or even out of the ring plane. Thus, some forces must tend to restore the gaps and the flatness. The widely accepted theory of these forces involves gravitational effects of the satellites, which all lie outside the rings. These forces, together with statistical effects of repeated gentle collisions, would tend to keep the ring particles confined to the present ring positions. However, Nobel laureate Hannes Alfven criticized this theory and proposed in 1968 that the gaps are "fossil" structures that reflect a different, primeval configuration of the satellites.

This idea remains controversial, but leads directly to the question: How did the rings form? The oldest explanation involves the concept of the *Roche limit*, a shell-like zone near each planet in which an orbiting satellite, depending on its internal strength, would be broken by tidal gravitational forces from the planet. The rings lie inside, or mostly inside, the Roche limit for large icy or stony satellites. Many astronomers have therefore assumed that the rings are debris from a satellite that fragmented because of the tidal forces. But recent re-analysis shows that a satellite would hardly form *inside* the Roche limit, and it is rather implausible to form one outside and then move it inside the limit.

A second theory is the "condensation" theory, which supposes that many fine particles condensed in the ring region while Saturn and the other planets were forming — but were prevented from collecting into a moon by the Roche forces. However, a recent major study by NASA scientist James B. Pollack shows that the fist sized ring particles probably could not have remained in ring orbits since the formation of the solar system. They would be affected by long-term solar-radiation-induced forces called Poynting-Robertson forces, and would spiral into Saturn. This leads to the exciting suggestion that the rings may not date back to the formation of Saturn, but may have formed more recently by a major collision between a meteorite and a satellite near Saturn, or perhaps slow erosion of such a satellite by many small meteorites. Perhaps three or four billion years ago Saturn had no rings!

As Pollack and other astronomers have emphasized, spacecraft flights near Saturn could help test and clarify our concepts of the rings. For example, a spacecraft on the far side of Saturn could view the sunlight transmitted through the rings — a perspective not available from Earth — which would help determine the reflecting, scattering, and size properties of the rings, perhaps clarifying in turn their composition and true origin. In the early 1980s we probably will get such a view as at least two Mariner class space vehicles are scheduled to swing by the ringed planet. Until then, Saturn observations from Earth will be conducted at an ever increasing rate.

In this view from above Saturn's north pole, we can clearly identify the planet's three main rings and their sizes relative to Saturn itself. Compare this perspective to the cover photo.

Artwork by Adolf Schaller

Dr. William Hartmann is a senior scientist at the Planetary Science Institute in Tucson, Ariz. He is author of the introductory text, **Moons and Planets** *(Bogden and Quigley, Inc., 1972), and co-author of* **The New Mars**, *a newly released NASA illustrated account of the Mariner 9 mission. He has contributed numerous articles on planetary science to* **Icarus** *and other research journals.*

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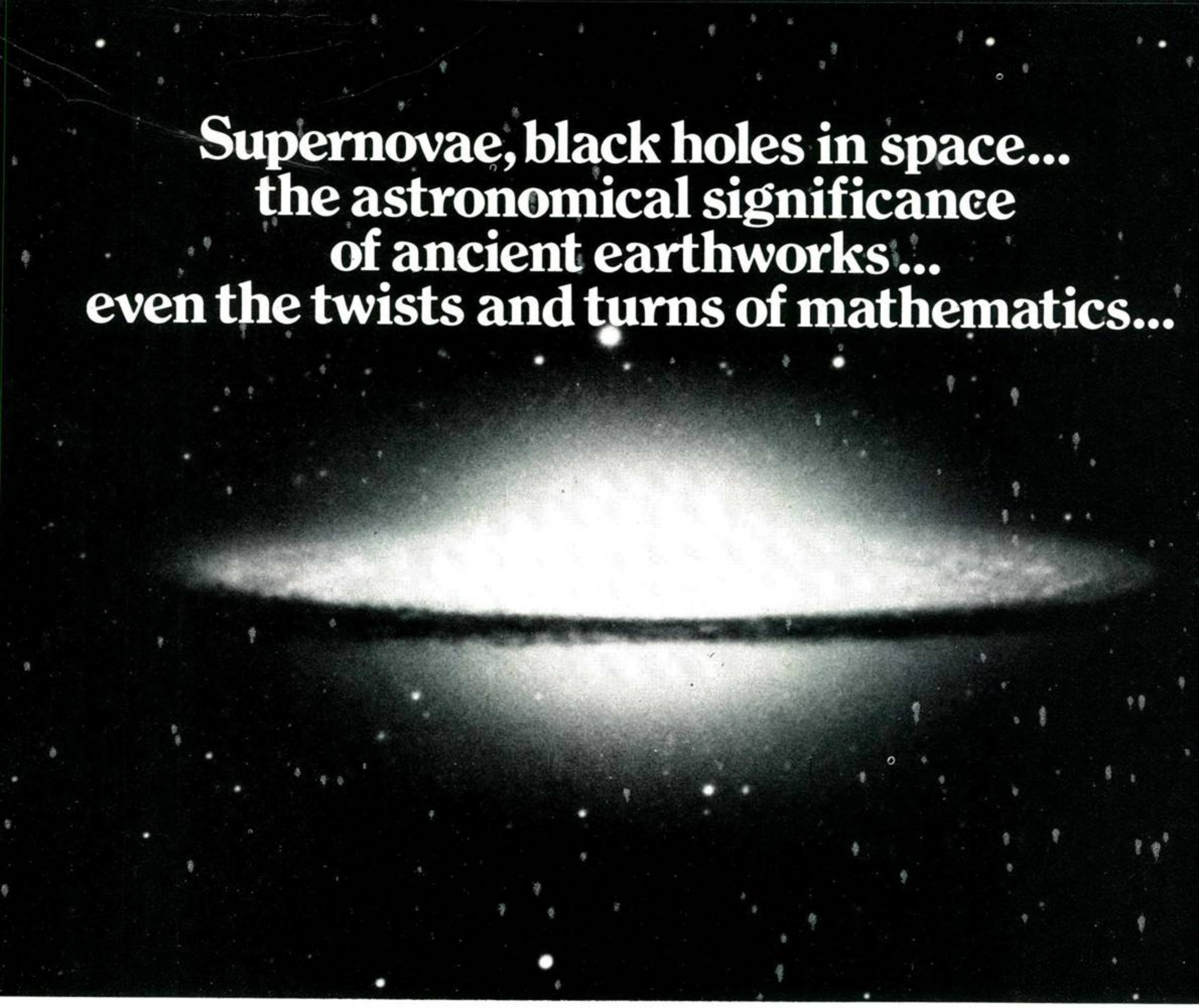

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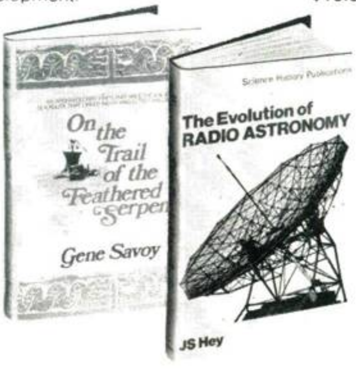
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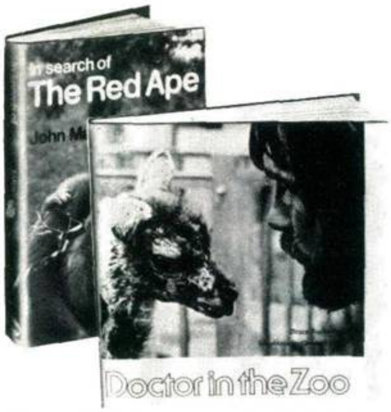

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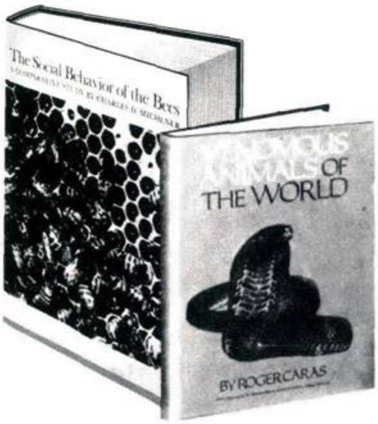
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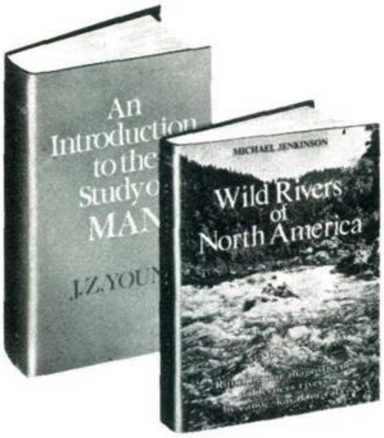
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Eros to Pass in Front of Bright Star

A once in a lifetime event involving the asteroid Eros is predicted for astronomy enthusiasts observing from along a narrow zone in the extreme northeast this month.

Venus is finally back (although barely) and Mercury will make one of its brief appearances. Jupiter and Saturn round out the midwinter month.

SATELLITE SHADOWS ON JUPITER

Date	Satellite	Transit Begins (EST)	Transit Ends (EST)
Jan. 1	2	6:57 p.m.	9:41 p.m.
7	4	7:30 p.m.	9:38 p.m.
7	1	8:00 p.m.	10:15 p.m.
8	2	9:33 p.m.	12:18 a.m.
14	1	9:56 p.m.	12:10 a.m.
16	1	4:25 p.m.	6:39 p.m.
23	1	6:20 p.m.	8:35 p.m.
23	3	3:15 p.m.	6:23 p.m.
26	2	4:04 p.m.	6:44 p.m.
30	3	7:17 p.m.	10:25 p.m.
30	1	8:16 p.m.	10:31 p.m.

1 = Io
2 = Europa
3 = Ganymede
4 = Callisto

Eros

This 15 mile wide flying mountain makes one of its once-every-44-year close approaches to Earth this month. Eros is a brick shaped asteroid that — unlike most asteroids — ventures well within the orbit of Mars. Most asteroids never stray from their primary domain between Mars and Jupiter, but late this month Eros will be only 14 million miles away.

The complete details of Eros' trip by Earth are given in "Rendezvous With Eros" in the October 1974 issue. One item that was not known when that article went to press was that of the predicted occultation of the third magnitude star Kappa Geminorum on the evening of Jan. 23, 1975. An occultation (passing in front) of even a faint star by an asteroid is a rare occurrence. The Eros occultation of such a bright star is unprecedented. Here is what will happen:

If you live along a path that extends from

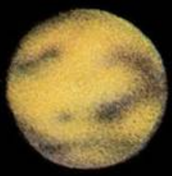
The scintillating draperies of the aurora borealis illuminated the sky over many of the northern states on Oct. 12, 1974. Brauer, of Bismarck, N.D., told us, "By midnight the display extended so far south that Jupiter was enveloped." This 15 second exposure was taken through a 58mm f/1.4 lens on a Minolta SRT-101 camera. The High Speed Ektachrome film was processed to ASA 400.

Photograph by Michael G. Brauer

Planet Finder

Ⓒ Cer

Jan.	1	15
R.A.	23h14m	23h29
Dec.	-15°09'	-12°5
Mag.	+8.3	+8.4



Ⓐ **Mercury**

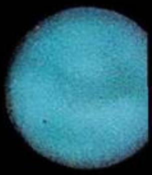
Jan.	1
R.A.	19h22m
Dec.	-24°14'
Mag.	-0.8

Ⓑ **Mercury**

Jan.	15
R.A.	20h56m
Dec.	-18°49'
Mag.	-0.7

Ⓜ **Mars**

Jan.	1	15
R.A.	16h57m	17h41m
Dec.	-22°53'	-23°44'
Mag.	+1.7	+1.7



Ⓝ **Neptur**

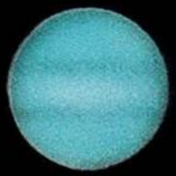
Jan.	15
R.A.	16h38
Dec.	-20°3
Mag.	+7.7

SUN

The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.

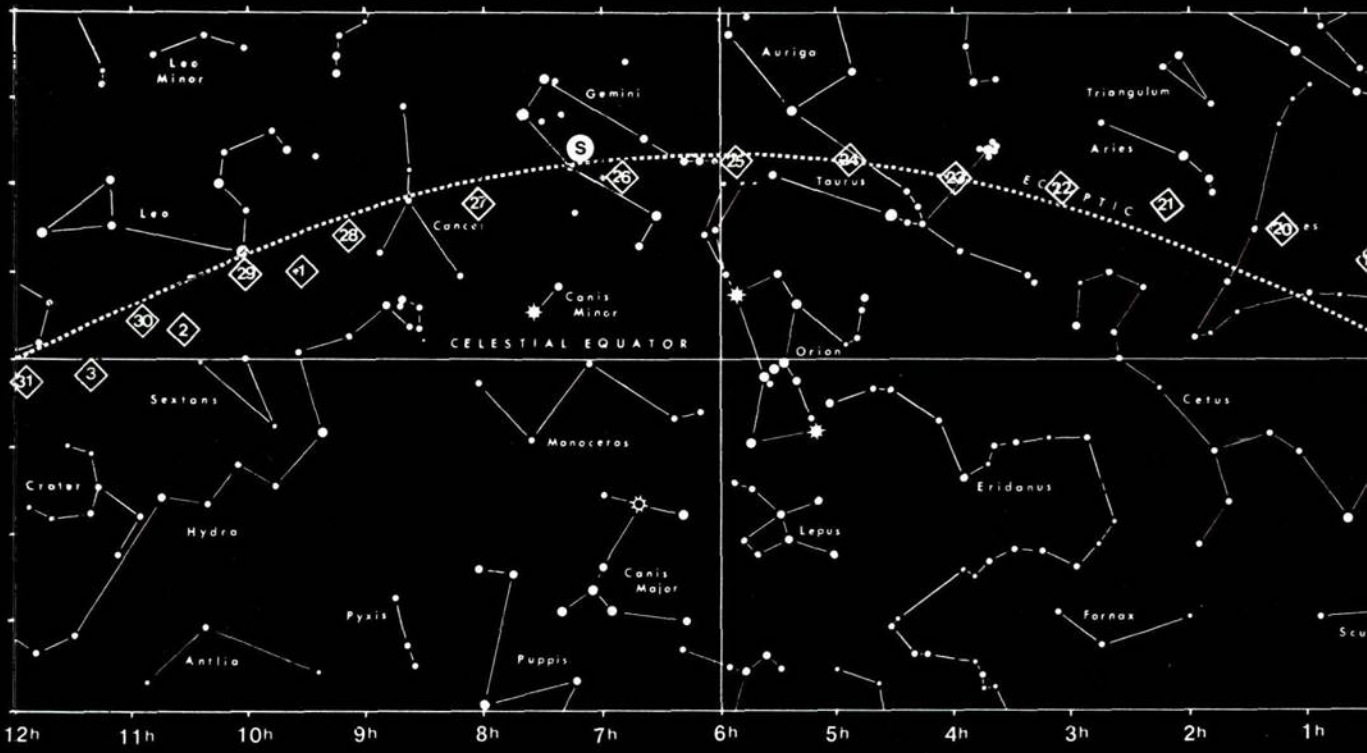
Ⓢ **Saturn**

Jan.	1	15
R.A.	7h08m	7h03m
Dec.	+22°06'	+22°15'
Mag.	-0.2	-0.2



Ⓤ **Uranus**

Jan.	15
R.A.	14h01m
Dec.	-11°45'
Mag.	+5.7



Leo Minor
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Cancer
Canis Minor
CELESTIAL EQUATOR
Auriga
Taurus
Triangulum
Aries
ECLIPTIC
Orion
Cetus
Sextans
Monoceros
Crater
Hydra
Eridanus
Lepus
Canis Major
Pyxis
Antlia
Puppis
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6h
5h
4h
3h
2h
1h

Map by Raymond G. Coutchie

The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and Dec. = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. Mag. = magnitude, a

January 1975

Ⓥ Vesta

Jan.	1	15
R.A.	18h38m	19h11m
Dec.	-22°40'	-22°21'
Mag.	+7.7	+7.7

Ⓙ Jupiter

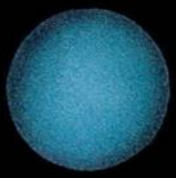
Jan.	1	15
R.A.	23h00m	23h10m
Dec.	-7°34'	-6°32'
Mag.	-1.8	-1.7

Ⓨ Venus

Jan.	1
R.A.	19h47m
Dec.	-22°26'
Mag.	-3.4

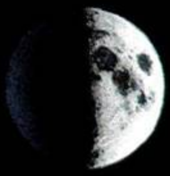
Ⓩ Venus

Jan.	15
R.A.	21h00m
Dec.	-18°35'
Mag.	-3.4



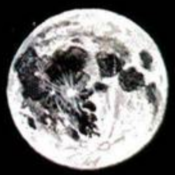
Ⓟ Pluto

Jan.	15
R.A.	12h59m
Dec.	+12°00'
Mag.	+14



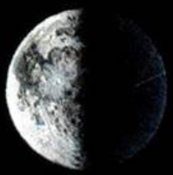
First Quarter

Jan. 20



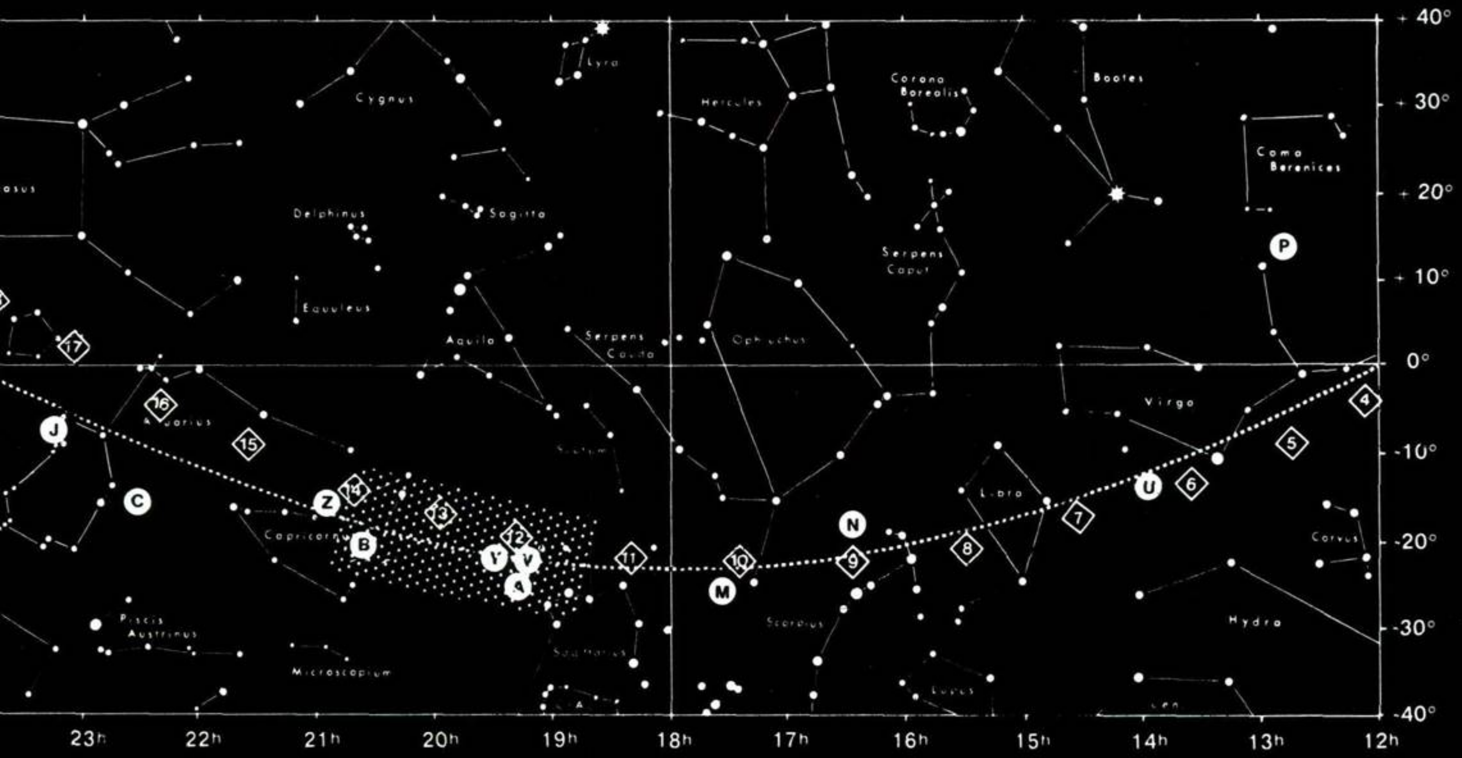
Full Moon

Jan. 27



Last Quarter

Jan. 4


Lyra
Cygnus
Hercules
Corona Borealis
Bootes
Coma Berenices
Delphinus
Sagitta
Serpens Caput
Equuleus
Aquila
Serpens Cauda
Ophiuchus
Aquarius
Virgo
Scutum
Libra
Capricornus
Corvus
Piscis Austrinus
Scorpius
Hydra
Sagittarius
Microscopium
Lupus
J
C
Z
B
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+30°
+20°
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-10°
-20°
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23h
22h
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19h
18h
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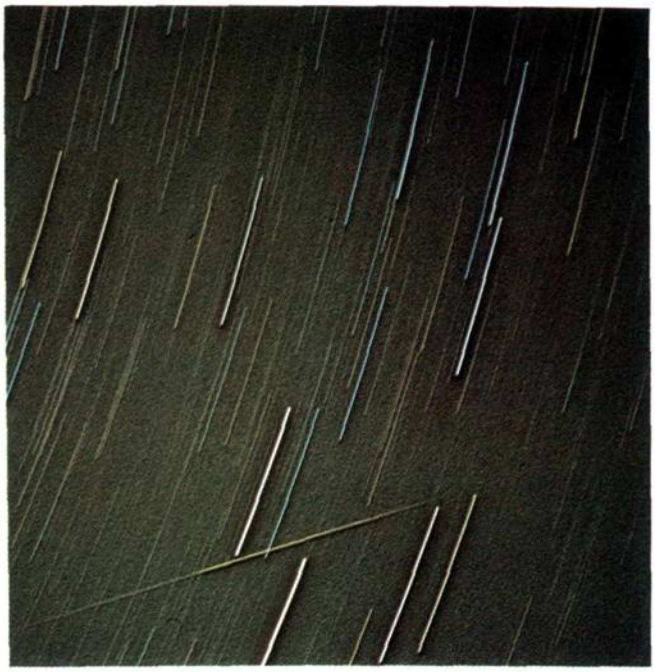
16h
15h
14h
13h
12h

measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) The diamonds with *numbers within them indicate the position of the moon for* each day of the month: the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th. Certain areas of this map and the Star Dome chart overlap each month.

Artwork by Victor Costanzo



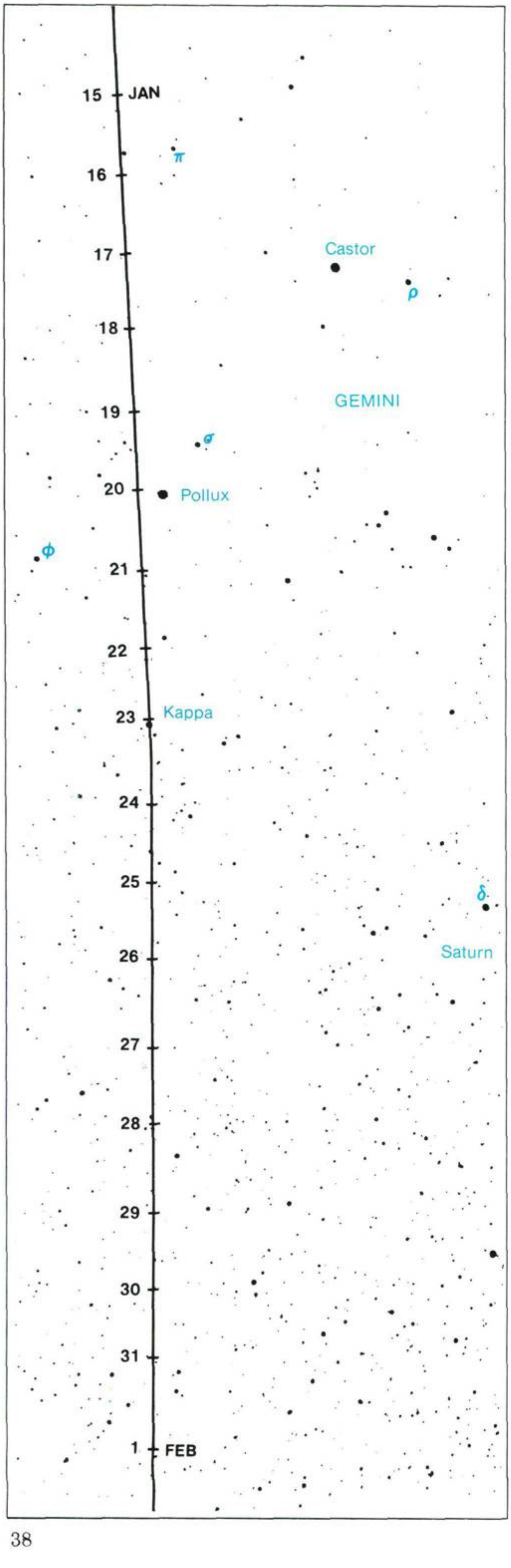
Photograph by William S. Ray

During his first try at astrophotography, Ray "caught" a Perseid meteor. Labeling the feat "beginners luck", Ray used the information provided in last August's Gazer's Gazette article on meteor photography.

Three Rivers, Quebec, through Maine between Bangor and Portland, you *may* be among the lucky ones. We say may because the exact location of the 10 mile wide occultation path has not yet been calculated as we go to press. But if you are anywhere near this zone be sure to be out watching Kappa Geminorum (see map) on Jan. 23. If the eighth magnitude Eros passes in front of Kappa, that naked eye star will blink out for up to 10 seconds!

Telescope users will have an advantage because they can watch Eros approach the star. If it doesn't occult it from where you are, it will pass very close by. The 3.7 magnitude Kappa has an 8.2 magnitude companion that is seven seconds from the bright star. That companion is about the same brightness as Eros if you want to practice a few nights early.

You should be glued to your telescope or binoculars from 7:15 p.m. to 7:25 p.m. — the time span when Eros will be nearest Kappa. Even unaided eye observers should be out if they live within 100 miles of the path. Our *Instant-News* subscribers will get a detailed update if one becomes available. (*Instant-News* is ASTRONOMY's service to subscribers who wish immediate notification of rapidly changing or new celestial phenomena. Subscribers can join the service by sending 10 self-addressed stamped envelopes and $2 to *Instant-News*, AS-



The path of the asteroid Eros through Gemini this month may include an ultrarare occultation of the third magnitude star Kappa Geminorum at approximately 7:20 p.m. EST, Jan. 23. Positions of Eros on the dates indicated are for 7:00 p.m. EST. This month, Saturn will be a few degrees west of where it was when this photo was taken.

Photograph by Leo C. Henzl Jr.

TRONOMY, 757 N. Broadway, Suite 204, Milwaukee, Wisc. 53202.)

Readers who have stop watches that read to 1/10 of a second should record the duration Kappa is obscured. If you send your observation to us, we will forward them to the appropriate data reduction center. Such measurements may aid in determining the exact shape and size of Eros.

Saturn

The astronomy enthusiast's showpiece is nearest Earth on Jan. 6 when the two planets will be separated by 748 million miles. Saturn's distance throughout the month is never more than 10 million miles greater than that value — making this the month for Saturn viewing. Tips on observing this planet are given in this month's Gazer's Gazette.

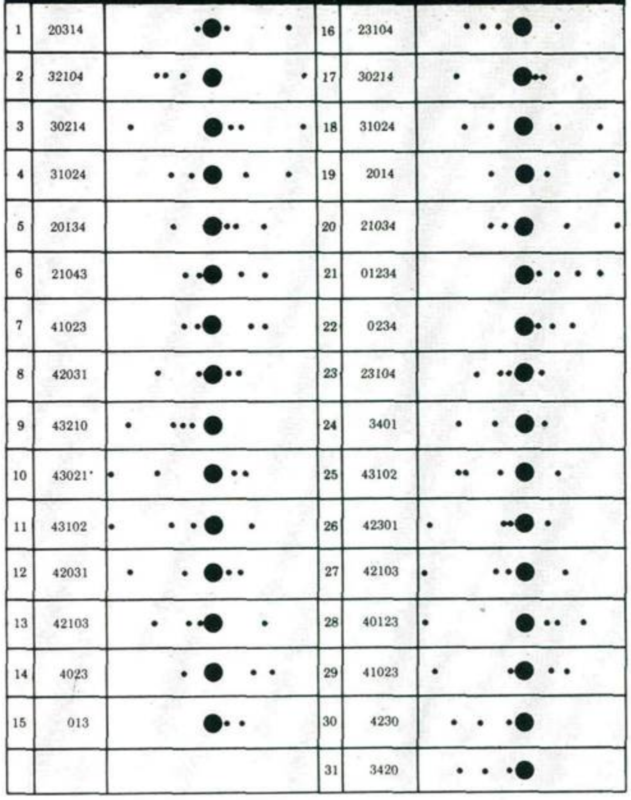
Saturn's rings are 46.6 seconds of arc in width for the first two weeks of January. By month's end they shrink slightly to 46.1 seconds. For most of the month, the planet's magnitude is -0.2.

Jupiter

Well past its prime, the big planet shrinks from 36.9 seconds in equatorial diameter on the 1st to 34.5 seconds by the 31st. During the month its magnitude drops slightly from -1.8 to -1.7. Distance from Earth ranges from 495 million miles to 530 million miles.

Perseid meteor and aircraft lights by Henry Ferguson

SATELLITES OF JUPITER
January

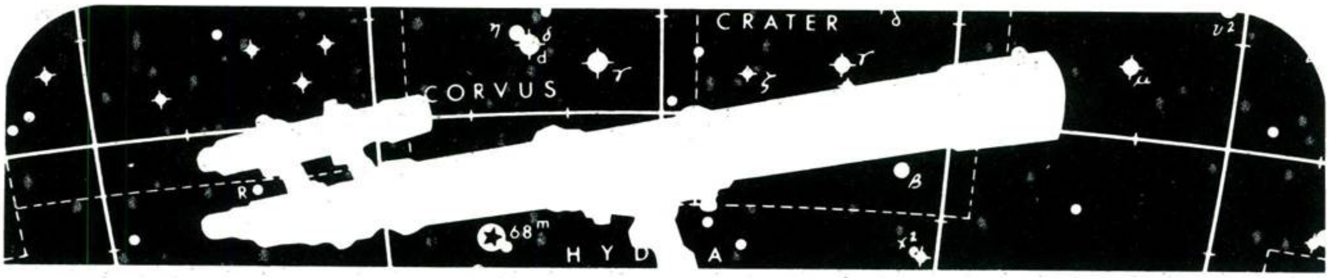


1	20314	16	23104
2	32104	17	30214
3	30214	18	31024
4	31024	19	2014
5	20134	20	21034
6	21043	21	01234
7	41023	22	0234
8	42031	23	23104
9	43210	24	3401
10	43021	25	43102
11	43102	26	42301
12	42031	27	42103
13	42103	28	40123
14	4023	29	41023
15	013	30	4230
		31	3420

The four major satellites of Jupiter orbit the giant planet in periods ranging from just under 2 days to 17 days. They can be seen to change position from night to night. Sometimes their motions become evident after only a few minutes' observation. Only a small telescope is required to detect all four of the satellites and several can frequently be seen in rigidly held binoculars. This table shows the approximate positions of the moons at about 8 p.m. (EST) on the evenings indicated. First column on the left shows the date. Second column of numbers identifies the moons and their positions relative to Jupiter's disk. (1 = Io; 2 = Europa; 3 = Ganymede; 4 = Callisto, and 0 = Jupiter's disk.) The third column approximates a telescopic view of the satellites' positions. The orientation of the satellites is shown inverted as seen in a standard astronomical telescope.

Mercury and Venus

From the 15th to the 25th these two planets will be within a few degrees of each other very low in the southwest at dusk. Mercury will be about magnitude -0.5 while Venus is 15 times brighter at -3.4. Telescopic observation of either planet will be difficult because of their low elevation, but photographers may want to try to capture the two inner planets in this relatively rare sustained conjunction. Both planets will be in improved observing positions later this year.



EQUIPMENT ATLAS

Getting to Know Your Telescope

Part 1: The Equatorial Mounting

For an estimated half million Americans, astronomy is a fascinating hobby. It's an interest that can be enjoyed for a lifetime with only modest expenditure of time and money. Your local library has a stock of astronomy books that can introduce the wonders of the universe via pictures and descriptions. Newspapers and science magazines offer a smattering of astronomy articles, and magazines such as this further satisfy a curious mind.

But for most of us that's not enough. The moon's brilliant face beckons to be examined in detail. The planets, once you discover their locations, are never fully appreciated until they too are seen through the eyepiece of a quality telescope. And beyond the solar system there are the stars, nebulae and galaxies in countless profusion — all silently awaiting telescopic examination.

Astronomy is a participation hobby. No photograph or description can duplicate seeing the delicate division in Saturn's rings or the faint swirling wisps of the Orion nebula through the eyepiece of your own telescope. It's hard to explain the satisfaction that accompanies comprehensive knowledge of the sky. It probably has something to do with being able to find celestial objects and thereby experience some feeling of cosmic awareness in its purest sense.

But let's get down to practicalities. You can't fully appreciate the celestial banquet if you are unable to utilize the full potential of your telescope. If your relationship with your telescope is something less than one of complete confidence, then read on.

Let's suppose you just received a new telescope for Christmas. It doesn't really matter what brand it is or what type of telescope. Whether a refractor, Newtonian reflector, Schmidt-Cassegrain or Maksutov, the problems encountered by the beginner are common to practically every instrument. Any telescope worth using by an astronomy enthusiast who considers himself at all serious about his hobby will have an equatorial mounting. Let's concentrate on that first.

The equatorial mounting can be distinguished in one of several ways. First of all, it is the most expensive type of mounting that the manufacturer offers for the particular size telescope that you have. (Virtually all telescopes over four inches aperture are offered only on equatorial mounts.) Secondly, it at first seems to be more complicated and harder to use than the altazimuth or simplified mounting. (The altazimuth mount is one that has horizontal and vertical functions only.)

A typical equatorial mount is pictured on page 44; that photo shows a German equatorial mounting. The only other type commonly seen supporting small telescopes is the fork equatorial mounting. Equatorial mounts look formidable to the uninitiated. The problem is that explanations of their use are often brief and not explicit enough for someone totally unfamiliar with not only their operation but the purpose in having an equatorial mount in the first place. Let's take it step by step right from the beginning.

Your telescope is in its packing case and there are instructions inside that (presumably) give you complete details on how to assemble the instrument. Following those instructions, you should have little

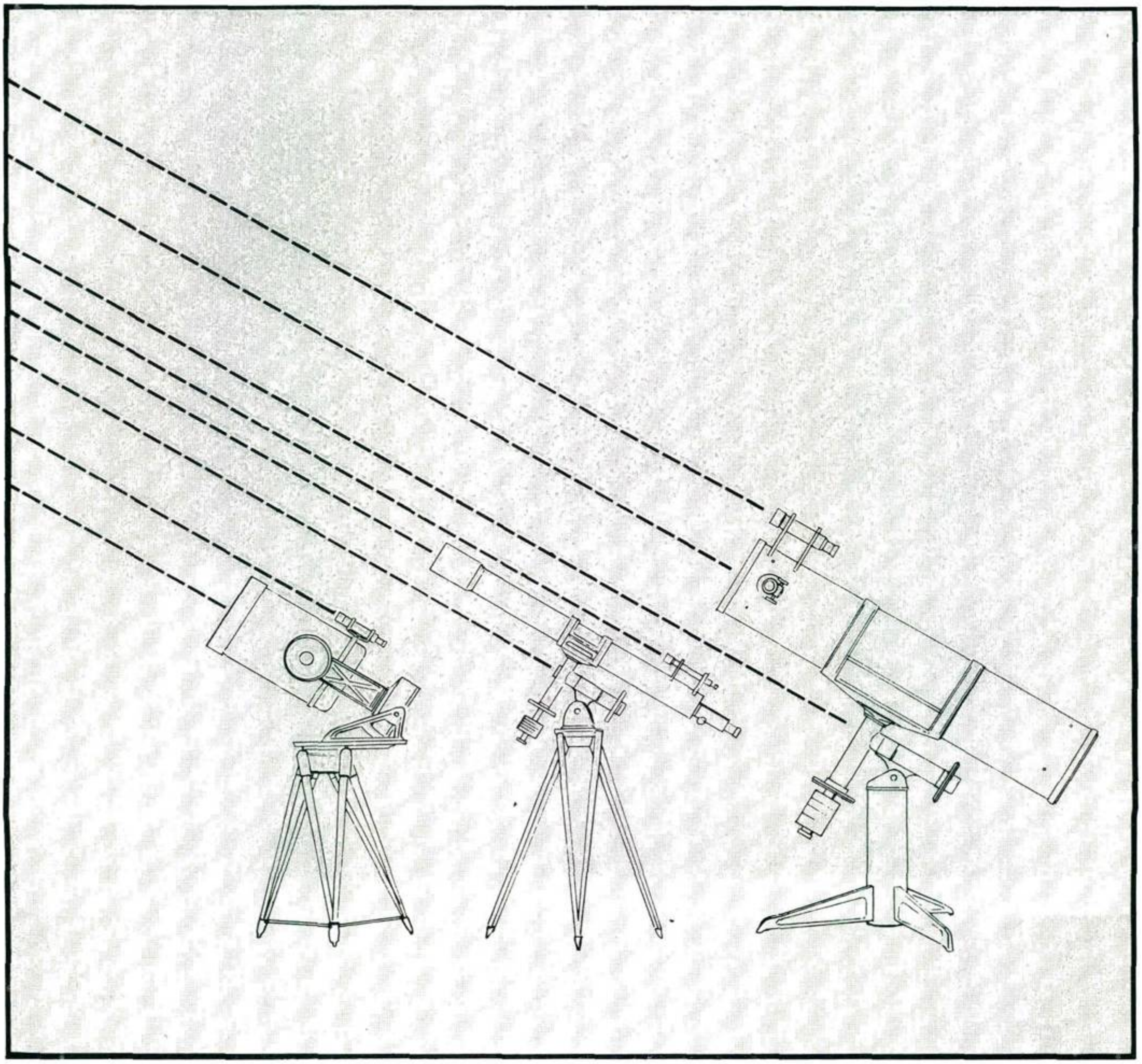
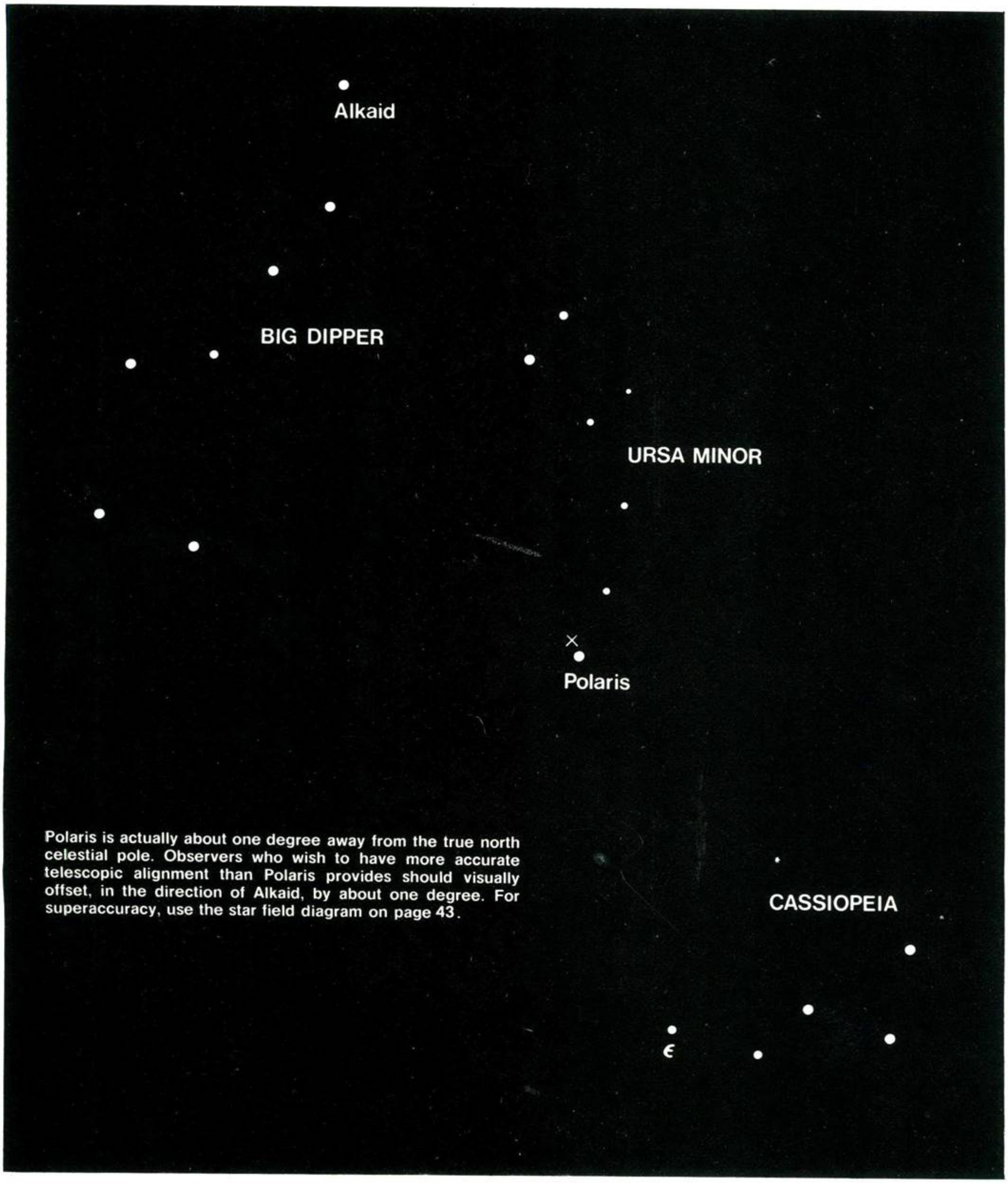


Diagram by Victor Costanzo

The three main types of equipment used by astronomy enthusiasts are illustrated here. Each telescope tube has been set so that it is parallel to the polar axis. (Having the declination setting circle at 90 degrees should put the scope in this position.) With all telescope motions locked in this position the tripod legs should be adjusted to bring Polaris near center in the finderscope. The telescope now parallels Earth's axis and is ready for general sky gazing.



Polaris is actually about one degree away from the true north celestial pole. Observers who wish to have more accurate telescopic alignment than Polaris provides should visually offset, in the direction of Alkaid, by about one degree. For superaccuracy, use the star field diagram on page 43.

difficulty putting it together. Once assembled, your telescope will look like one of the sketches on page 41, where the basic principle of the equatorial mount is illustrated. That principle is having one rotational axis of the scope parallel to Earth's rotational axis. As our planet rotates from west to east the telescope can be rotated on its polar axis from east to west, precisely counteracting the motion that makes sky objects seem to drift out of your telescopic field of view. Thus, turning only one knob — the one that rotates the polar axis — will do the job. If your scope is equipped with an electric drive motor, no manual compensation is needed to keep sky objects in view.

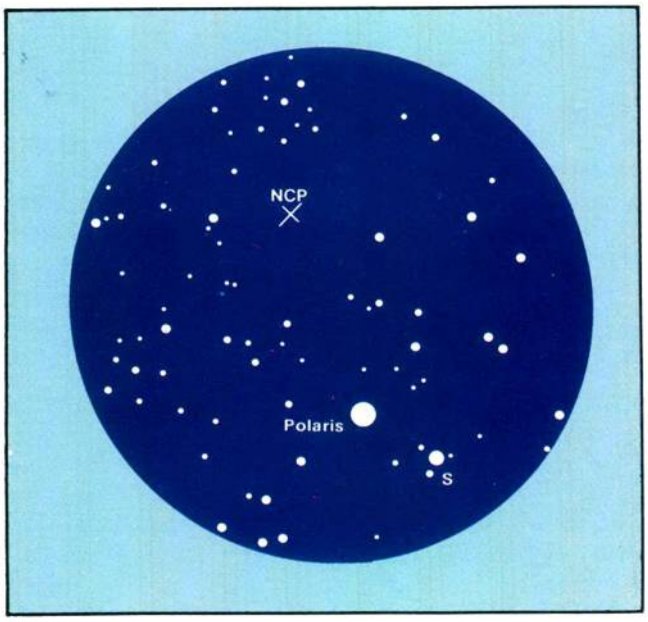
However, it's not quite that simple. The telescope has to be aligned near the north celestial pole before all this will work. This is not easily accomplished unless your telescope's polar axis is adjusted to your latitude — a procedure that may or may not have been done at the factory. The best time and place to make the latitude adjustment (which will be permanent until you move) is in your own backyard on a typical clear night. For this particular task you may want to set up in daylight or dusk so you can see what you are doing, and then make the actual adjustment at night. Here is the procedure:

(1) Set up your scope on concrete, asphalt or dry, hard ground in a location that permits a clear view in the north toward Polaris.

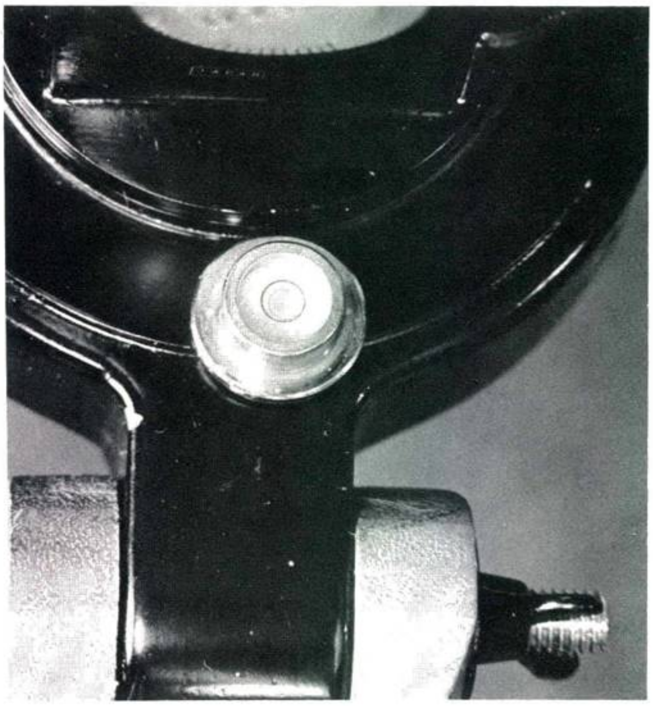
(2) By shifting the tripod legs (or adjusting the leveling screws on a pedestal type mount), bring the tripod head to a level position. A "bull's-eye" level is best for this purpose as illustrated on this page. A carpenter's level can also be used.

(3) Loosen the bolt that locks the polar axis so that the part of the mount above the bolt moves when moderate pressure is applied. Do not loosen this bolt too much because it will make the scope dangerously unstable. (The bolt we refer to here, in case you aren't sure, is almost always a large one just above the tripod head — the one being adjusted in the photo on page 44.)

(4) Swing the telescope tube so that it parallels the polar axis. If your telescope has setting circles, this is easy — simply set the declination circle to read 90 degrees. (There are two 90 degree positions; use the one that points the telescope skyward.) Most commercial equatorial mounts have setting circles; but if yours doesn't, you'll have to guess at this. Surprisingly, eyeball alignment in this case is usually adequate. Lock all telescope motions except for the one loosened in step #3.



This two degree diameter circle includes Polaris, the north celestial pole (NCP) and surrounding stars down to 13th magnitude. Although no star is located at the exact NCP, you should have little difficulty locating the exact point. From Polaris, first identify the seventh magnitude star marked "S". All the other stars are much fainter making S obvious. From there the other stars should be easy to locate. Remember, accurate alignment on the NCP is only necessary if you plan astrophotography or use of the telescope's setting circles.

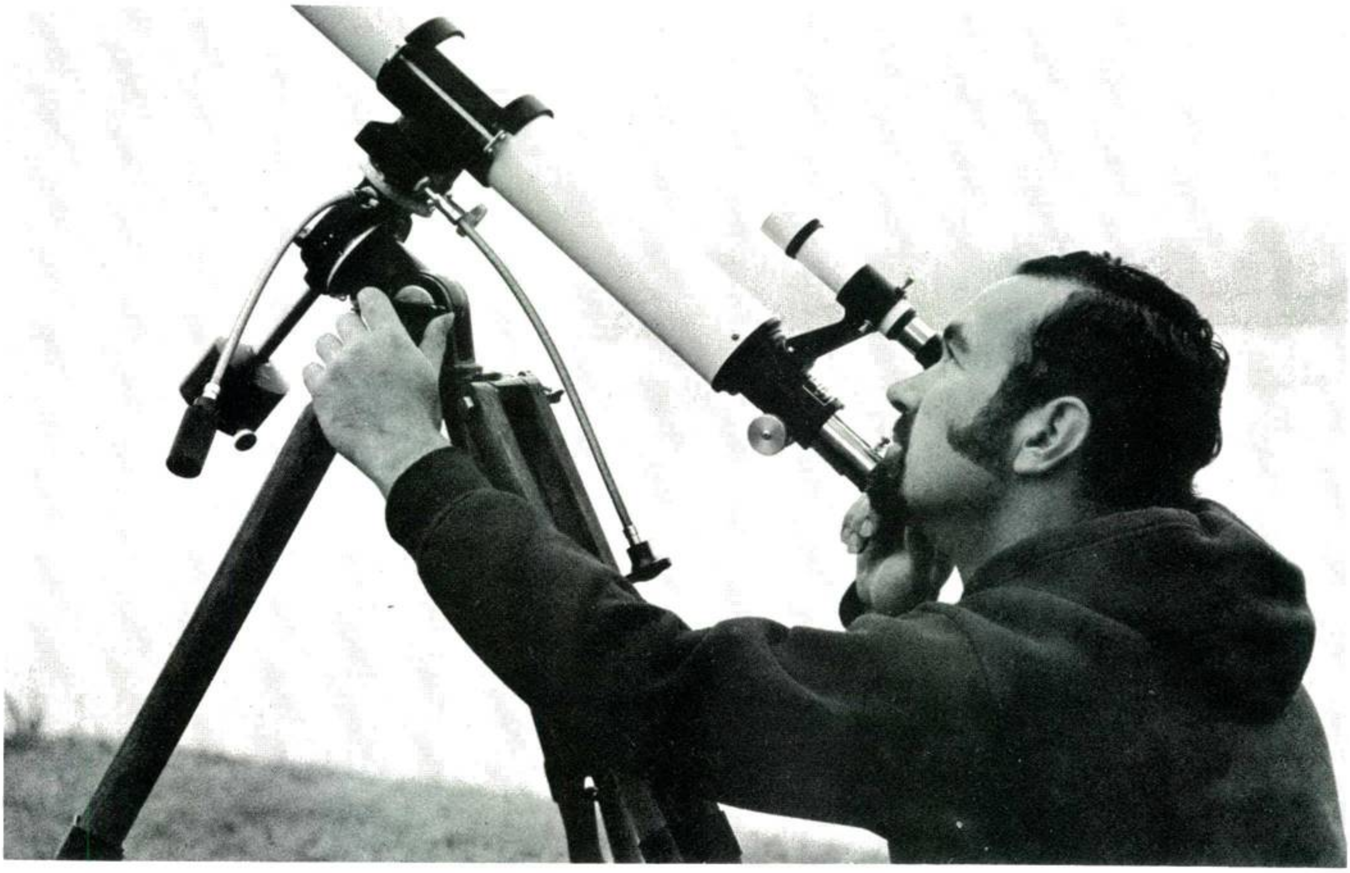


To initially adjust your telescope's polar axis to your latitude, you must first insure that the mounting head (the flat plate just above the tripod legs) is level. The small bulls-eye level is adequate for the purpose. These levels can be obtained at hi-fi equipment or hardware stores. Once leveled, the polar axis should be locked on Polaris as shown in the photo on page 44 .

(5) Use your finderscope and move the telescope until Polaris is near the center of the field of view. (This assumes you have checked to make sure the finderscope's cross hairs are adjusted to the same infinity point the main telescope points to.) If this movement requires adjusting the tripod, you will have to re-level the head. Thus, it's a good idea to set up with the telescope pointing as close as possible to Polaris in the first place. With the head level and Polaris near center in the finder, tightly lock the polar axis. Check everything again with the bolt tight. It will not be necessary to unlock this bolt until you move to a new latitude.

This may sound somewhat complex but keep in mind it's an infrequent procedure; once properly done you can forget it. The reward is that you can now take full advantage of your equatorial mount.

Tomorrow night all you need to do is lock all rotational axes in the same position as outlined above and adjust the tripod legs until you get Polaris approximately centered in the finderscope. Precise leveling is not required anymore. This will put you within two or three degrees of the north celestial pole — but that's good enough. More precise alignment on the north celestial pole is necessary only if you wish to conduct guided astrophotography



With the mount properly leveled, the polar axis bolt is loosened and the telescope moved up or down until Polaris is approximately centered in the finder. The bolt is then firmly tightened. Precision accuracy is not necessary for this procedure; a one or two degree error will not be noticed. Once this latitude adjustment is made, the polar axis bolt should not be touched again. For future setups, lock your telescope as shown in the diagram on page 41 and aim at Polaris. Adjust the tripod legs to bring that star near center in the finderscope. No leveling is necessary from now on.

or plan to use your setting circles. (Use of setting circles will be discussed in a future issue.)

Easy? It certainly is. There's nothing mysterious about an equatorial mount. Once you are set up, it's a simple matter to point your scope, turn on the drive, and then spend your time watching the sky show without interruption. (We'll stick to theory here and ignore the neighbors' kids, the landlord's 2,000 watt yard light and the usual quantity of clouds.)

Rough alignment near Polaris, as we mentioned, is adequate for most observing situations. Let's now consider precise alignment necessary for guided astrophotography — such as that described in this month's Photography in Astronomy.

Polaris is less than one degree from the apparent pivotal point of the sky. To precisely counteract Earth's rotation it is necessary to have your telescope's polar axis directed as close as possible to the exact north celestial pole. There is only one way to do this and it requires the use of the telescope's declination scale. (Of the two setting circles, the declination scale is the one that is marked in degrees from 0 to 90 and back to 0.) On any quality telescope, this scale is set at the factory and should not be tampered with.

With the declination scale set exactly at 90 degrees, and all telescope motions locked, adjust your tripod footing until your low power telescopic eyepiece field is centered on Polaris. Since the spot we are interested in is less than one degree from Polaris (luckily), we can use that bright star to advantage this way: Select an eyepiece that gives you about a one degree field — that's twice the apparent diameter of the moon. This eyepiece will allow you to have Polaris and the faint pole region stars in the same field of view. Without getting lost, you can identify these faint stars and then confidently center them by tripod adjustment. (The map on page 43 gives the exact location of the true pole for 1975. A ponderous wobbling of Earth changes the position of the celestial poles but the shift is imperceptible for periods under a decade.)

You will now have a perfectly aligned telescope capable of precision tracking of any celestial object. To check this, focus on a star near the celestial equator — a star in Orion is good — and watch for drift, north or south. If none occurs you're in business. If you do encounter problems at this point check your procedure again. If problems still persist, we will probably get to them in an upcoming article on setting circles.

An excellent guide to subjects related to those discussed in this article is "All About Telescopes" by Sam Brown, available from Edmund Scientific Co.

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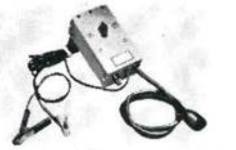

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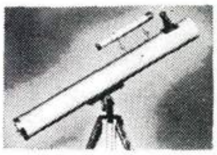

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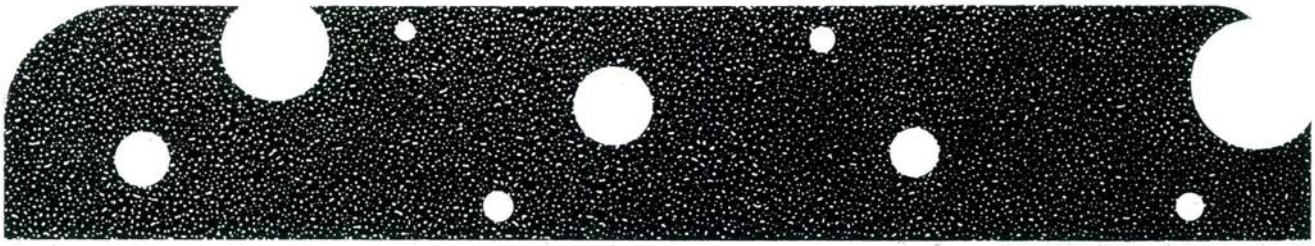


STELLAR FRONTIERS

Why Does the Crab Nebula Shine?

by
Gerrit L. Verschuur

The Crab nebula was once a star. In the year 1054 that star destroyed itself in the violence of a supernova explosion. The eruption was witnessed by Chinese astronomers and probably by American Indians in the southwest United States. It shone brightly for several months — so bright that it was visible by day.

A supernova is obviously a very chaotic event, but we generally don't think too much about the way the light from such an explosion is generated. It would seem obvious that it should produce a lot of light. Don't all explosions?

There are a few questions we should ask about various aspects of the supernova phenomenon. The first is: Why does it happen? Related to this we wonder which stars will explode. (This is sort of a personal concern since we are, after all, orbiting a star.) Another question is: What actually happens when the explosion occurs? That is, what generates the light, radio, and X-ray signals? Finally, why do we continue to see the supernova remnants after the explosion? In the case of the Crab nebula, it is some 900 years since the blast. So why is it still shining? This question applies equally well to the remains of other supernovae.

We will try to give some answers to that last question here. (The first two questions are answered in varying degrees of detail in the articles mentioned at the end of this department.) Since the Crab nebula is one of the most thoroughly studied objects in the universe outside the solar system we will concentrate on it as our best example.

As long ago as 1945 Walter Baade discovered that photographs of the Crab nebula showed variations from year to year, and even from month to month. The changes were traced to the core of the nebula where several wisps of material seemed to be involved. This was the first indication that the Crab nebula was still "alive". Baade and Rudolf Minkowski suggested that one of the two stars that lie near these wisps was possibly the collapsed remains of the star that originally exploded. We now know that they were right. The lower of the two central stars in the Crab nebula is a pulsar.

Pulsars are thought to be the highly condensed, collapsed cores of stars that have erupted in supernova explosions. A colossal magnetic field riddled with intensely high powered energy is wrapped around the 10 mile wide pulsar. The pulsar is, in effect, the power generator for the nebula. The way it injects energy into the nebula is quite fascinating.

The photo on page 49 showing the central zone of the Crab shows "Wisp 1", a feature that actually moves backward and forward changing its apparent position by about two seconds of arc every couple of years. Since we know the distance to the Crab nebula (about 6,000 light-years), this can be interpreted as "something" moving with speeds as large as 30 percent of the speed of light. The wisp has been

The Crab nebula is the most intensely studied celestial object outside the solar system. This glowing cloud of celestial rubble was once a mighty star that ended its existence in the fury of a supernova explosion 921 years ago. The erupting outer layers swirled outward to form the nebula we see today. The star's collapsed core is a 10 mile wide pulsar — the lower of the prominent pair of stars near the center of the nebula. What keeps the nebula shining so long after the explosion that created it has only recently been answered, as explained in this article. This photograph is a color-correct version that duplicates the visual appearance of the nebula. Unfortunately the Crab is one of those objects that shows up well in long exposure photos like this, but is a faint hazy patch in most telescopes.

Lick Observatory Photograph

measured to physically move about 1/20 of a light-year.

In 1969 Jeffrey Scargle at Lick Observatory collected photographs which show the way this wisp changes its shape and position with time. He later found that these changes were directly related to activity in the pulsar itself.

The pulsar in the Crab nebula was discovered in 1968 as a result of detection of radio signals emitted by it. The pulses are incredibly regular, repeating once every 33 milliseconds (that is, 30 times per second). After this discovery the central stars were photographed with a camera system whose shutter was synchronized to the radio pulsar period. The star we identified earlier as the pulsar was observed to be actually flashing on and off at the same rate as the radio pulsar.

Even while pulsars are emitting very constant bursts of radiation, the repetition rate of the pulses is gradually slowing down from year to year. All pulsars are in fact running down, much as a watch will do if it is not wound.

Then something unusual was discovered. The Crab pulsar suddenly speeded up, and then proceeded to slow down just as it had before. This was called a "spin-up" and it was thought that a sort of "starquake" had taken place on the surface of the pulsar. Perhaps the neutron star surface had realigned itself in some way, much in the way an earthquake will reshape the surface of Earth. In the neutron star the quake might have caused the star to get a little smaller which would cause it to speed up slightly.

After several spin-ups Scargle studied his photographs of the crab nebula and its wisps, and found that changes in the wisps occurred about 60 to 80 days after each spin-up. He concluded that whatever had caused the spin-up also caused something to move out from the pulsar (that is, the neutron star), and when that something reached Wisp 1 it pushed that wisp outward. Later Wisp 1 would move back to its original position. Sometimes the more distant wisps would also show changes in structure.

Careful thought indicated that no starquake could generate a phenomenon that would travel through space the distance out to the wisp. Instead, it appeared that what had happened was that something else had caused both the changes in the wisps and the spin-up.

We know that the pulsar is spinning very fast and we also know it has an incredibly strong magnetic field that gets continuously twisted as the pulsar winds it up. This will cause it to become unstable, which in turn will occasionally produce the equivalent of an explosion in the upper parts of the pulsar magnetosphere (the most intense part of the magnetic shells around the pulsar).

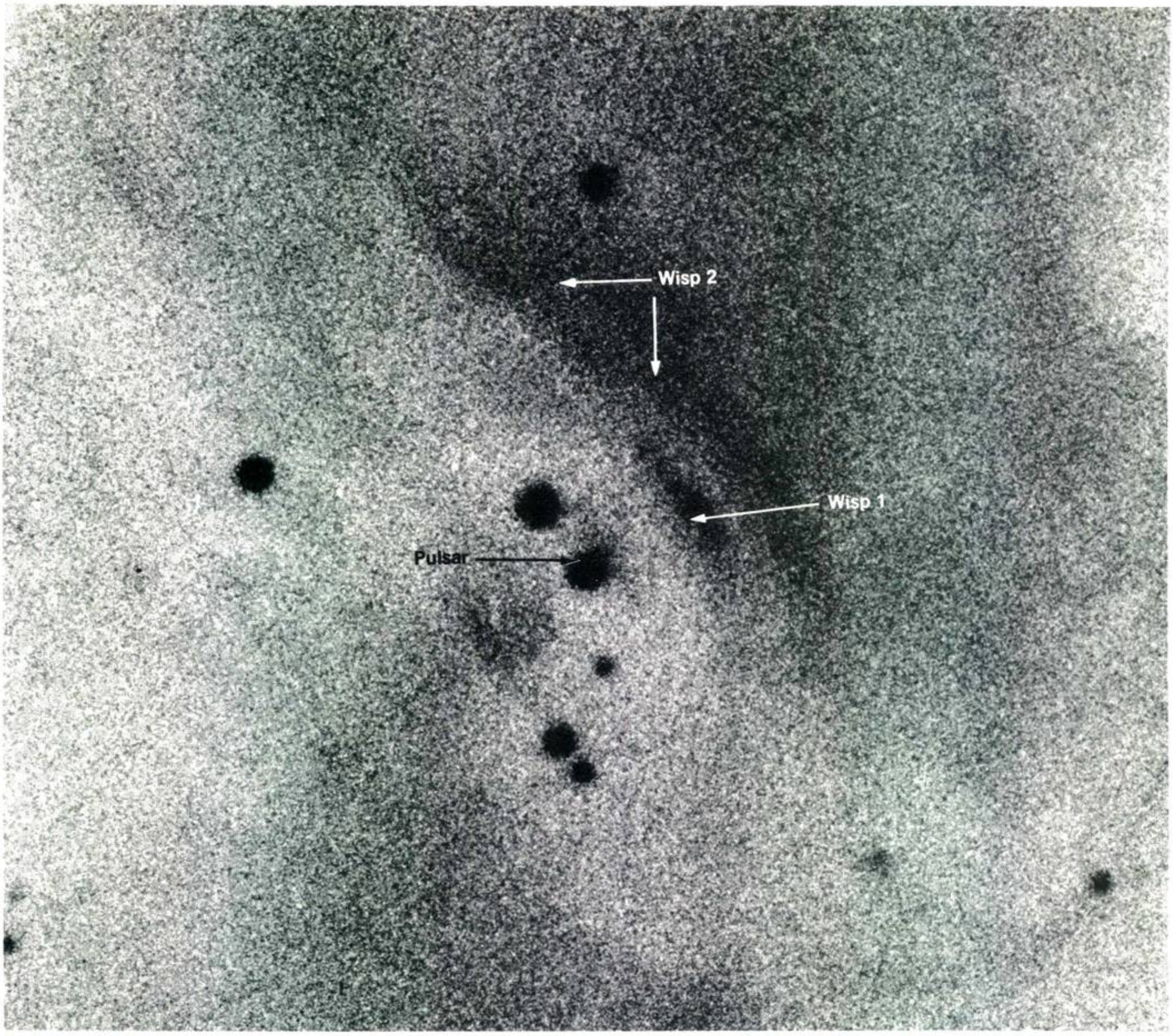
Such an explosion or rearrangement of magnetic fields would be similar to a flare on the sun. As a result, a strong blast wave of magnetic fields and particles moves out from the pulsar. Meanwhile, Wisp 1 is sitting out there. This blast wave from the pulsar hits it, and suddenly the wisp gets violently pushed around. At the same time, the abrupt change in the magnetic conditions around the pulsar cause the pulsar to momentarily speed up and then it continues to slow down as before. This slowing down continues for millions of years, it is believed. Such spin-ups have also been observed in other pulsars so the general slowing down with spin-ups superimposed seems to be normal performance for these bizarre objects.

Now we are partly on the way to understanding where the energy for the nebula comes from. It turns out that when the compression wave or blast wave from the pulsar hits Wisp 1 it can cause great changes in the magnetic field strength and structure in the wisp. Consequently conditions in the wisp become suitable for accelerating particles such as electrons, and these particles then spread out into other parts of the Crab nebula itself. There they proceed to spiral around the magnetic fields in the filaments which are so clearly seen in the nebula. They then radiate radio and light energy which we pick up here on Earth. Some of these accelerated particles also leak out into space and form part of the cosmic ray background in the galaxy.

To summarize: It is the reorganization of the magnetic fields near the pulsar (a few miles from it) that causes magnetic energy to propagate outward. It is then converted to energy of motion of particles in the wisp. In turn, it is converted to electromagnetic (light, radio waves, etc.) radiation which we can see here on Earth.

To get back into the center of the nebula, though, it turns out that this is an intermittent process and that it is not the only process that causes energy to get out into the nebula. The pulsar itself is constantly spinning — some 30 times per second. It is thought that the magnetic axis of the pulsar is not aligned with the rotation axis, much as Earth's magnetic north pole is not at the geographical north pole. The spinning pulsar's magnetic field becomes a generator of 30 cycles per second radiation. Of course we know the pulsar sends out pulses at this frequency, but we are now talking about something different. The pulses are thought to come from regions above the magnetic poles and every time we look down certain magnetic field lines, we pick up a pulse. On the other hand, the 30 cycles per second radiation we must now consider is an actual electromagnetic wave, just as a radio or light wave is an electromagnetic wave of a certain frequency.

This 30 cycle wave finds it difficult to go very far, and it gets absorbed by the matter in space around it (which is, of course, the matter in the Crab nebula itself). This means that the energy of rotation of the pulsar gets converted into a wave and



Lick Observatory Negative Photograph

The central part of the Crab nebula contains several "wisps" of matter that have been observed to change position over periods as brief as weeks. The details of these changes are described in this article. The pulsar and surrounding stars shown here can be located near the center of the nebula in the photo on page 46. The Crab nebula is about one light-year in diameter.

this wave gets absorbed by the nebula, where it is converted into energy. This is energy of motions of electrons and protons in the nebula, which in turn means that they contain energy available for emission of light and radio signals.

The actual surface structure of pulsars is not accurately understood, but astronomers believe that the spinning pulsar magnetic fields cause currents to flow on the surface. The 30 cycle per second radiation is produced by these currents. At the same time, some of the electrons that make up these currents will blow out into space in the form of a strong wind. The sun also generates a constant wind of matter into space, but by a different process. The winds from the pulsar are available for feeding even more energy into the surrounding nebula. The first process mentioned above — that of the sudden instability — can be thought of as a sudden increase in this basic pulsar wind which flows out into space until it loses all its energy and can blow out no further. It is in that region of space that the wisps are thought to exist — the region where the wind exhausts itself and matter piles up against the surrounding nebula.

The existence of these three processes is inferred by careful study of mountains of data and the application of a lot of theory. Now that it's done, we can — for the first time — understand why the Crab nebula is still shining brightly out there, some 6,000 light-years away, 900 years after the explosion.

Other articles on the Crab nebula and pulsars can be found in the following issues of ASTRONOMY: "Hercules X-1: How to Weigh a Pulsar", October 1973; "Life on a Neutron Star", December 1973; "Magnetic Fields Beyond Earth", March 1974.

Magnificent Saturn

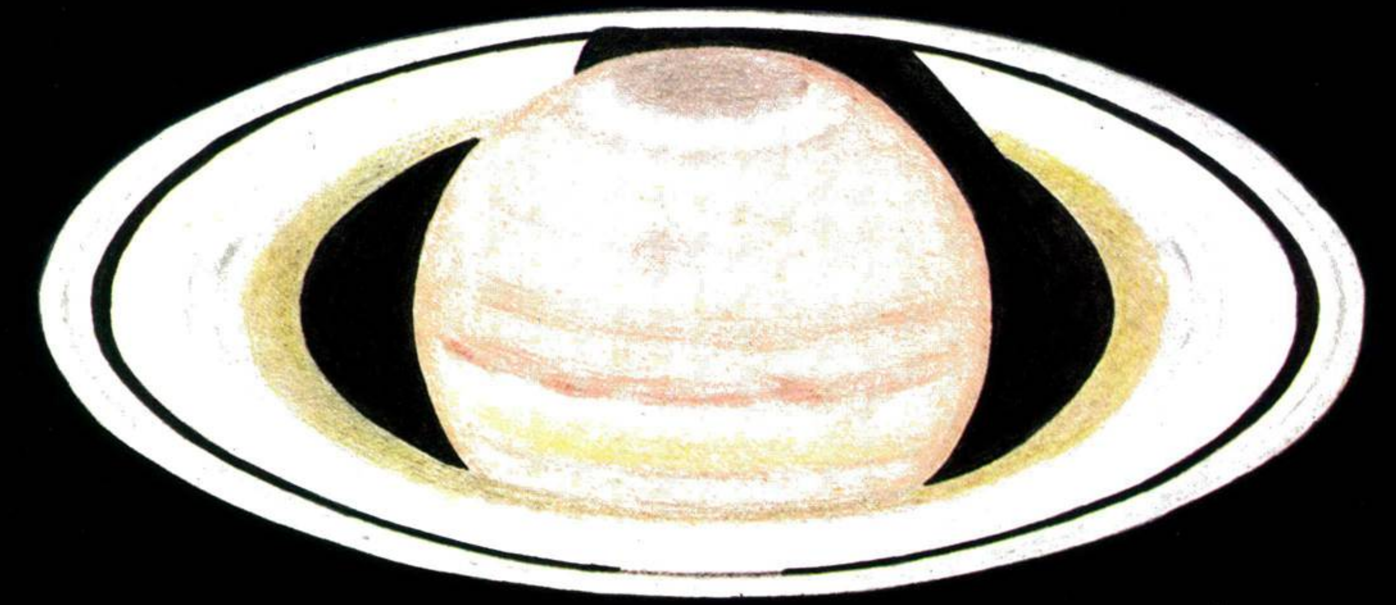
If you had to choose the one celestial object that surpasses all others as an object of exquisite beauty and unforgettable splendor, it would have to be Saturn. Saturn is the superstar of the night sky — a dazzling showpiece unmatched by anything else visible in a telescope.

Everyone remembers that first telescopic view of Saturn. The chilling beauty of the small, pale orb floating in a field of velvet is something no photograph or description can adequately duplicate. This is one instance where you have to see it to fully appreciate it.

SATURN'S SATELLITE FAMILY

Name	Magnitude	Orbital Period (days	hours)	Distance from Saturn (miles)	Minimum Aperture for Detection
Janus	14.0	0	18.0	100,000	*
Mimas	12.1	0	22.6	116,000	12 inch
Enceladus	11.8	1	8.9	148,000	10 inch
Tethys	10.3	1	21.3	183,000	6 inch
Dione	10.4	2	17.7	235,000	5 inch
Rhea	9.8	4	12.5	327,000	3 inch
Titan	8.4	15	23.3	759,000	2 inch
Hyperion	14.2	21	7.6	920,000	12 inch
Iapetus	10 to 12	79	22.1	2,213,000	3 inch
Phoebe	16.5	523	15.6	8,053,000	*

*** detected only with photographic techniques**



Drawing by Lawrence M. Carlino

Significant artistic skill is required to make an accurate representation of Saturn, and few observers even make the attempt. The details of this rendering were sketched at the eyepiece of a 10 inch Cave Newtonian reflector on Feb. 7, 1974. Using 216 to 305 power, Carlino noted not only the wide Cassini division but also Encke's division near the center of the outer ring. A few hints of divisions in the bright ring are seen but experienced Saturn observers suspect that these are transient. The so-called crepe ring is the innermost of the three and is recorded here as a dull gray-green. The belt structure on the planet itself shows some subtle detail just at the limit of resolution. Seeing conditions were rated at 6/10.

If you've seen Saturn in a two inch or larger telescope you know what we're talking about. Even at 25 power, the rings can be distinguished — but the view improves with larger scopes.

The image of Saturn in a 10 or 12 inch telescope often exceeds the finest photographic portraits of the ringed planet. The true dimensions of the planet are easy to underestimate. The rings of Saturn are the widest substantial object in the solar system apart from the sun.

The orbit of Saturn is an immense 29.5 year circuit about the sun. In the course of an observing season (say four months or so), the planet moves relatively little in its orbit and thus appears to remain about the same place among the stars. This year that place happens to be the constellation Gemini, as the photo on page 38 illustrates.

As Saturn orbits the sun we are treated to a 15 year cycle that swings the rings from their maximum tilt of 27 degrees down to zero degrees, or edge-on. They were last edge-on in 1966; then they gradually opened to full view in 1973, and now they are slowly closing again to another edge-on aspect in 1980.

The principle involved in this cycle is the same one that governs the seasons here on Earth — the tilt of the planet's axis. Saturn's south pole is tipped 25 degrees toward the sun (and us) this year; consequently the rings, which hover precisely over the planet's equator, are equally tipped for our inspection. Earth does the same things as viewed, for example, from the sun. First the northern hemisphere is presented to the sun; then six months later, the southern. In the case of Saturn's large orbit, first its northern hemisphere and north face of the rings are tipped to Earth and the sun; then 15 years later, the southern hemisphere and south side of the rings are presented to our view.

The brilliant rings are more reflective than the clouds that enshroud the planet. When the rings are open to the extent that they are this year, Saturn appears almost as bright as it possibly can be — magnitude -0.2 — to the unaided eye. This will make it brighter than everything in the overhead region of the sky this winter.

Saturn (probably more than any other planet) can be viewed using very high telescopic powers. Perhaps this is because of its low surface brightness (due to its tremendous distance from the sun). From 30 to 50 magnifications per inch of telescope aperture will give excellent views of Saturn if the atmosphere is at all calm.

The prominent 4,000 mile wide gap in the rings — called Cassini's division — can be seen with a three inch refractor under good conditions and is easily observed with four inch and larger telescopes. A second division, Encke's, is located about midway through the outer, smaller ring and usually requires at least a six inch telescope; sometimes even a 12 inch instrument will not reveal it. Other divisions in the rings have been reported but none are within

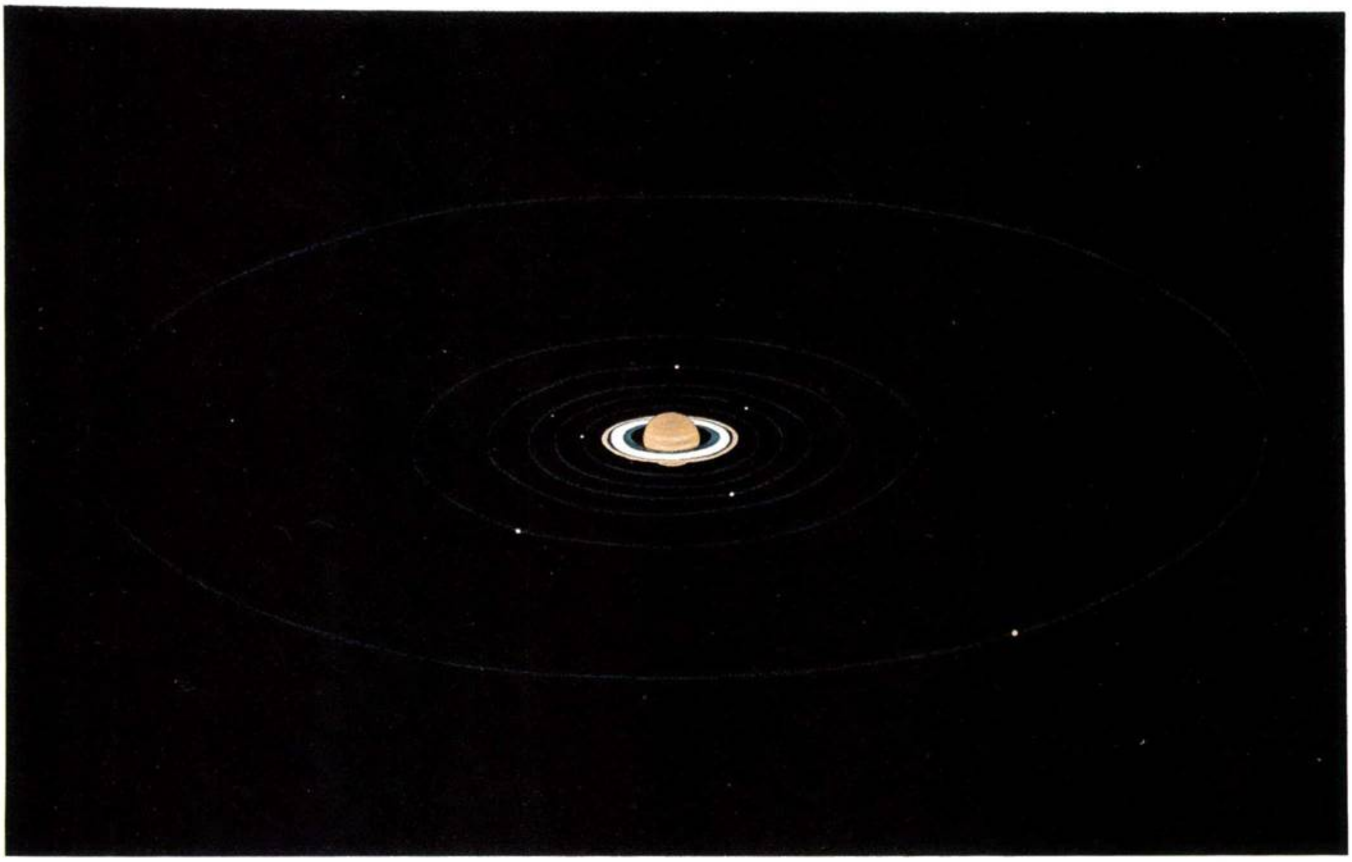
Photograph by Leo C. Henzl Jr.

range of amateur instruments even if they do exist. (The nature of the rings is fully described in the article beginning on page 26.)

In smaller telescopes — less than four inches — Saturn itself appears as an essentially featureless sphere, about 1/6 the size Jupiter appears through the same telescope at the same power. However a larger telescope should reveal the planet's whitish equatorial zone and the darker polar regions. The equatorial zone is particularly light in hue this year according to some of our readers.

Basically Saturn has a belt system like Jupiter's but it is much less active and the overall contrast is lower. Both Jupiter and Saturn have immense atmospheric cloaks that are topped by multicolored ammonia clouds. But the colors and activities in the Saturn clouds are a poor second to Jupiter's bold stripes. Only in large telescopes used on nights of good seeing do more than one or two belts come into view or any evidence of cloud features become apparent. Very rarely a spot among the clouds of Saturn will appear unexpectedly, but less than a dozen notable spots have been recorded since observation of Saturn by telescope commenced in the 17th century.

These spots have, however, proved to be vital in determining the rotation period of the clouds at various latitudes. On the equator for example the rotation period is about 10 hours 14 minutes. The belts on either side of the equatorial zone have an average rotation period of 10 hours 17 minutes and beyond that the atmospheric circulation slows down



Artwork by Victor Costanzo

In a 10 or 12 inch telescope, under conditions of good seeing, seven of Saturn's 10 satellites can be detected. Six are shown here along with their orbital paths. They are, in order from Saturn: Mimas, Enceladus, Tethys, Dione, Rhea and Titan. The seventh, Iapetus, has a much larger orbit than Titan. Rhea and Titan are easily seen in small scopes, but the inner four are harder to detect with Mimas and Enceladus most difficult to see because of glare from Saturn itself. To avoid confusing the moons, you can consult the table on page 53 which gives dates and times when the satellites are at their extreme eastern orbital points. In this rendering, south is at top and east to the right, as in a normal astronomical instrument.

Photograph by Craig McCaw

Saturn's rings were slightly more open to our view one year ago (when this photo was taken) than they are now. The 16 inch reflector at the Dominion Astrophysical Observatory was used for this GAF 500 photo.

considerably to about 10 hours 37 minutes in the zones between 35 and 40 degrees from the equator. Up around the poles it's something like 11 hours, but this is still debated. Paradoxically these large differences in atmospheric circulation suggest that there should be very active cloud activity at the shear points between belts. Yet the atmospheric activity appears to be low.

OBSERVING SATURN'S MOONS

Date	Time	Satellite	E or W
Jan. 2	4:15 p.m.	Rhea	E
3	9:45 p.m.	Dione	E
4	9:30 p.m.	Iapetus	E
6	2:00 a.m.	Tethys	E
6	4:00 a.m.	Titan	W
7	4:30 a.m.	Rhea	E
7	11:15 p.m.	Tethys	E
9	9:30 p.m.	Tethys	E
11	5:00 p.m.	Rhea	E
11	5:45 p.m.	Tethys	E
12	2:45 p.m.	Dione	E
14	8:30 a.m.	Titan	E
14	9:15 p.m.	Dione	E
16	5:15 a.m.	Rhea	E
20	5:30 p.m.	Rhea	E
22	1:30 a.m.	Titan	W
23	1:30 a.m.	Tethys	E
23	1:30 a.m.	Dione	E
24	10:45 p.m.	Tethys	E
25	6:00 a.m.	Rhea	E
25	7:00 p.m.	Dione	E
26	8:00 p.m.	Tethys	E
28	5:15 p.m.	Tethys	E
29	6:15 p.m.	Rhea	E
30	6:00 a.m.	Titan	E

This table provides all the necessary information for identification of Saturn's satellites Titan, Rhea, Tethys, Dione and Iapetus. E or W refer to extreme east or west points of the satellites' orbits. For Tethys and Dione, only eastern elongations occurring during darkness in the United States are included. Use this table in conjunction with the illustration on page 52.

In any event the rotation period will not be at all as evident as it is in the case of Jupiter unless a rare spot happens to emerge during the next few months. Modern observers can probably make only one significant discovery about Saturn and that is the detection of one of these spots — usually a white oval — that will allow a fresh determination of the rotation of the clouds. Such spots are so rare that when they are seen they are named after the discoverer, like a comet.

Saturn controls a family of 10 moons — one of which, Titan, is larger than the planet Mercury and is known to have an extensive atmosphere of mainly methane gas. Titan orbits Saturn in about 16 days and when it is east or west of the planet appears about five ring diameters away from the center of Saturn.

Titan can be seen in a two inch or larger telescope. (Observing details are given each month in Sky Almanac.) Of the remaining moons, Rhea is the only one easily seen in telescopes less than six inches in aperture. Its orbit lies well within Titan's.

One of the most mysterious objects in the solar system is Saturn's ninth moon, Iapetus (pronounced eye-YAP-petus). For some totally unknown reason one side is six times brighter than the other. When this moon is to the west of Saturn it is 10th magnitude and can be picked up with a three inch refractor. (Look for it in the first two weeks of February about 12 ring diameters west of Saturn.) But when it reaches the opposite side of its orbit 11 weeks later it has faded to 12th magnitude and is difficult to find in a much larger scope. No satisfactory explanation has been offered to account for the unique nature of Iapetus.

Moons like Dione and Tethys make excellent targets for telescopes over six inches (see tables). They are often nestled in the glare of the rings but finding them is a rewarding pastime for the astronomy enthusiast who has a large telescope. Try using "averted vision" if you are having trouble. Look away from Saturn but concentrate on the region around it. Often a faint satellite will pop into view as it registers on the sensitive regions of the eye away from the center of vision. Janus, Hyperion, and Phoebe are beyond amateur instruments and Mimas and Enceladus challenge the experienced observer.

Saturn will be in perfect observing position for the first four months of 1974. Anyone who owns a telescope owes it to himself to spend several evenings enjoying one of the most inspiring sights in the known universe.

For tips on Saturn photography see Photography in Astronomy in the September 1974 issue. Some of Saturn's moons are discussed in detail in Astro-News, November 1974. The Pioneer 11 mission to Saturn is outlined in Astro-News, May 1974.

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In response to requests from our readers and schools, ASTRONOMY has just published a cumulative index to Vol. 1. This subject index covers August, September, October, November and December, 1973, which includes issue Nos. 1 through 5. Index to Vol. 1 is available for $1.00 each, including handling and first class postage.

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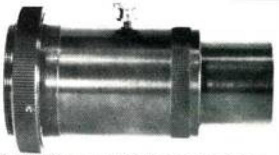

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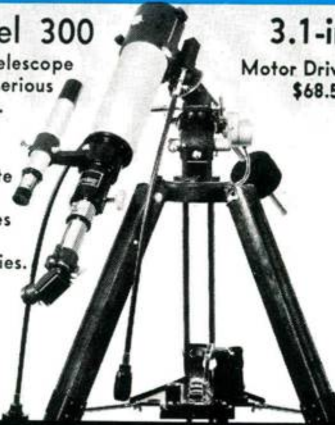

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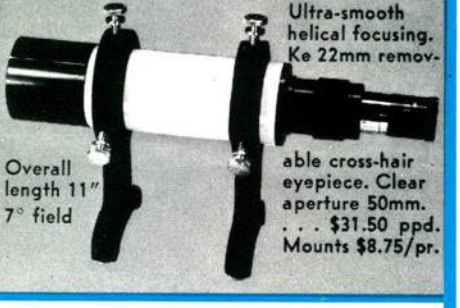

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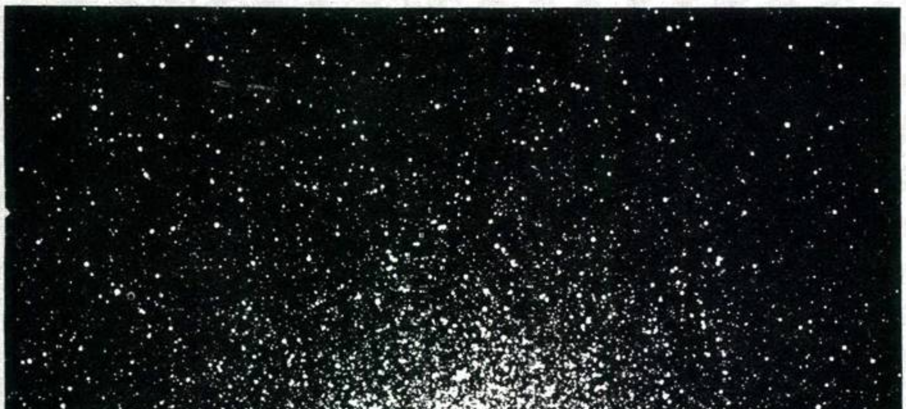
New Kitt Peak Twin Opens Southern Sky



Cerro Tololo Inter-American Observatory Photograph

The most spectacular view yet of the brightest globular cluster was the first scientific photo taken by the new 158 inch reflecting telescope at Cerro Tololo Inter-American Observatory in Chile. Named 47 Tucanae, the cluster is found in the constellation Tucana which is visible only from the southern hemisphere. This swarm of over one million stars is 35,000 light-years from the sun. The new telescope, second largest in existence, promises unprecedentedly detailed observations of the southern sky.

For over a generation the southern hemisphere has been without a major observatory comparable to those in the United States. Now the completion of a 158 inch reflecting telescope at Cerro Tololo Inter-American Observatory in Chile promises astronomers their best look yet at celestial objects clearly visible only from south of the equator.

From observatories located in the northern hemisphere, only about 3/4 of the entire sky is visible — the remaining part never rises above the southern horizon. In this portion of the sky not seen from the northern hemisphere are some extremely intriguing astronomical objects — the Magellanic Clouds, nearest galaxies to us, bright globular star clusters, and our own galaxy's center passing almost directly overhead.

Along with its near twin at Kitt Peak National Observatory in Arizona, Cerro Tololo's new instrument ranks as the world's second largest telescope, representing more than a decade of work by opticians, engineers and astronomers throughout the U. S. (A slightly smaller telescope is nearing completion in Australia, while a 237 inch giant being built in Russia is destined to become the world's largest.)

The heart of the new telescope is a four meter (158 inch) diameter mirror formed at the Owens-Illinois Co. "Among the very large telescope mirrors, the Cerro Tololo mirror is unequalled in its optical perfection," emphasizes Kitt Peak director Leo Goldberg. More than 30 months of grinding and polishing at Kitt Peak's optical shop went into making the

Kitt Peak *continued on page* **56**

Phantom Meteorite Foils Press

At 10:10 p.m. on Nov. 14, 1974, a brilliantly burning object flashed across the skies of the far Northwest. Fifty minutes later two army helicopter pilots near McKenna, Wash. closed in on what they believed was a fresh meteor crater blasted by the ball of fire.

"Even through the clouds there was a floodlight effect, like looking into a murky swimming pool that has its lights on," reported co-pilot John James. Hovering over the oval ring of fire, the pilots estimated that the object dug a crater 100 feet long by 20 feet wide.

The following day newspapers throughout the country were announcing a major meteorite impact. While nearby townspeople worried that the United States government would steal their prized meteor away, the local Civil Defense director mistakenly warned that meteorite fragments were lethally radioactive. (Maybe he confused it with Kryptonite's effect on Superman.)

"That helicopter report first made us suspicious that a meteor hadn't really fallen," says astronomer Paul Hodge. "Meteors usually don't start forest fires, much less dig oblong craters."

Some elliptical craters do exist but they're extremely rare. Such a crater could only be blasted by a meteor fragmenting into two parts just before impacting — an event occurring perhaps once every 100,000 years.

Hodge, Don Brownlee and Dan Tomandl (all University of Washington astronomers) emphasize that the circular fire and the glowing object were two very unrelated events. "All we have here is a fireball mistaken for a meteorite," explains Hodge. A fireball is a large meteor making a spectacular plunge through the atmosphere. But unlike meteorites it disintegrates before reaching the ground. Ninety percent of the sizable meteors colliding with Earth die as fireballs.

Evidence for their beliefs comes from the fact that since no shock wave was heard, the meteor probably burned up 10 to 20 miles above Earth. Seismic recordings also failed to show anything smashing into that area.

A helicopter search for signs of an impact was hindered by foggy weather, and after a few days the sheriff's department gave up looking for the phantom crater.

Scientists are still sifting through the many conflicting sightings of the fireball. Their best guess for now is that it really burned up about 150 miles north of the reported impact site.

What about the mysterious circular fire? Brownlee is convinced that it was simply a "slash" fire (brush burned off after logging operations) started by one of the many lumber camps in the area.

"People see a fiery thing in the sky and automatically connect it with a fiery thing on the ground," Brownlee says. "People don't grasp the size and magnitude of these events. They see a fireball disappear over the horizon and think it landed a couple miles away, when actually it was 80 miles away."

"Three times a year on the average we have fireballs here in the Northwest," Hodge points out, "but this time the coincidence of a brush fire saw the report getting to the press before even getting to us."

As with the "invisible" Kohoutek, many red faced newsmen will probably look the other way the next time a fireball streaks by.

Kitt Peak

continued from page **55**

mirror the largest of its kind ever produced.

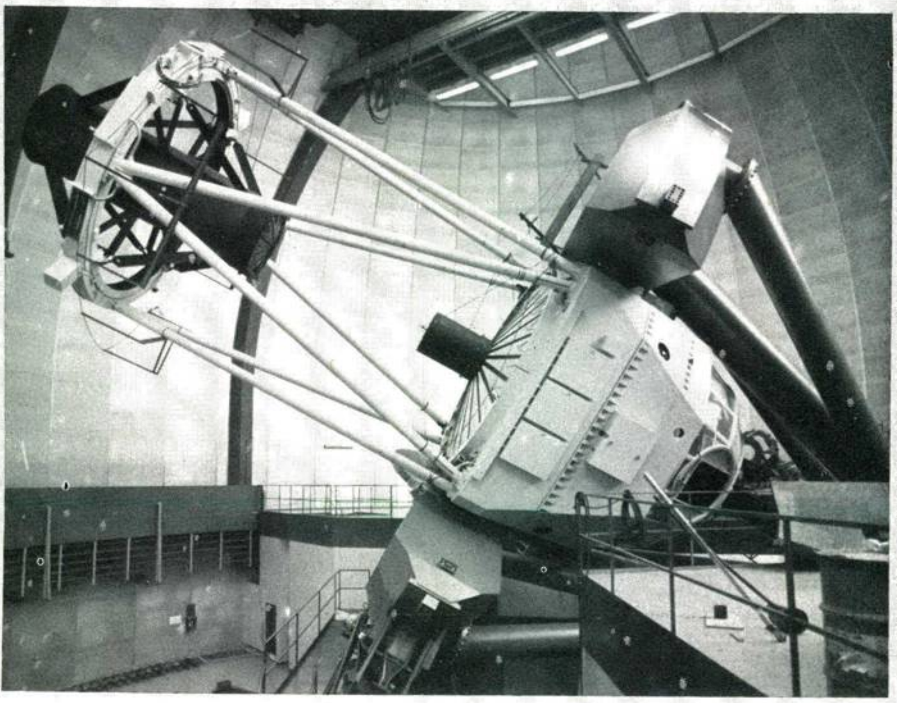
"The first research programs for the new telescope are being carefully selected," says Victor Blanco, director of the Cerro Tololo facility. "We want to take advantage of the telescope's outstanding optical features at the prime focus — namely the large light collecting area, fast f/2.6 speed and the mirror's optical perfection. All these conditions allow us to record extremely faint objects with remarkably short exposure times.

"The examination of star clusters, the search for faint nebulae, and the intense exploration of Large and Small Magellanic Clouds are among high priority programs for the new telescope," explains Blanco.

The observatory's first celestial target was 47 Tucanae, the sky's brightest globular cluster. Using a light gathering power one million times greater than that of the human eye, the instrument produced the spectacular photograph of 47 Tucanae appearing on page 55.

Globular clusters are groups of old stars that remained together after their creation, gravitationally bound by the sheer numbers — and masses — of stars populating the cluster. Over 100 globular clusters form a spherical halo around our Milky Way galaxy.

The observatory sits atop a 7,200 foot Andean mountain located 250 miles north of Santiago, Chile. Unusually stable and clear climate conditions assure Cerro Tololo of an especially clean window to the universe.



Cerro Tololo Inter-American Observatory Photograph

Inside the 13 story observatory at Cerro Tololo, Chileis the world's second largest telescope — the twin of the 158 inch instrument at Kitt Peak, Ariz. A 375 ton equatorial mounting supports the optical giant, which will go into full operation after about a year of testing and alignment.

What Caused Siberian Collision?

Shortly after midnight on June 30, 1908, an explosion unleashing all the deadly violence of a multimegaton nuclear warhead rocked western Siberia, hurling tremors halfway around the globe. Four hundred miles from the blast, wind gusts tossed horses around like stuffed toys while observers 250 miles away gasped at a hellish pillar of fire climbing skyward. Forty miles away a farmer's shirt burned off his back.

Reaching the blast site in 1927, explorers were amazed at finding trees leveled within a 20 mile radius. A meteor crash seemed the only phenomenon capable of creating such devastation, but strangely missing were meteoric debris or an impact crater.

After 65 years, the Tunguska, Siberia catastrophe remains a mystery. Armed with new discoveries in physics and astronomy, however, scientists are now offering bizzare new explanations for the incident.

How about a misplaced chunk of antimatter? Out of particle physics labs emerged the idea that maybe somewhere in the universe there exists matter electrically opposite to the stuff of Earth (normally negative, electrons would have a positive charge; protons, a negative charge). Mixing our matter with this antimatter would trigger a bang — ounce for ounce more powerful than even the fury of nuclear fusion, as atoms of either material electrically annihilate each other. By simply contacting our atmosphere, an antimatter meteor could have exploded above the Siberian forest — neatly explaining a crater's absence.

More farfetched speculations say the Siberian blast was a nuclear device detonated by a visiting alien spacecraft (a) malfunctioning, (b) self-destructing (to keep us from finding the pieces), or (c) doing it for kicks.

The latest idea, proposed by A. A. Jackson and Michael Ryan of the University of Texas, claims Earth was literally pierced by a black hole "bullet".

Astronomers normally think of black holes as fantastically compressed remains of dead stars. A black hole's unthinkably powerful gravitational field would instantly swallow up any nearby world of about Earth's size. What Jackson and Ryan have in mind is a "mini" black hole, created during the universe's explosive birth. No bigger than a speck of dust, it could weigh an incredible million billion tons.

They believe the encounter went like this: Smashing into Earth at a 30 degree angle (according to tree fall patterns), the microscopic missile fires shock waves through the atmosphere before burrowing into Earth's crust. Twelve minutes later a blast on the floor of the North Atlantic Ocean signals the bullet's abrupt exit. More shock waves thunder across the ocean as it zips through the atmosphere and back into space.

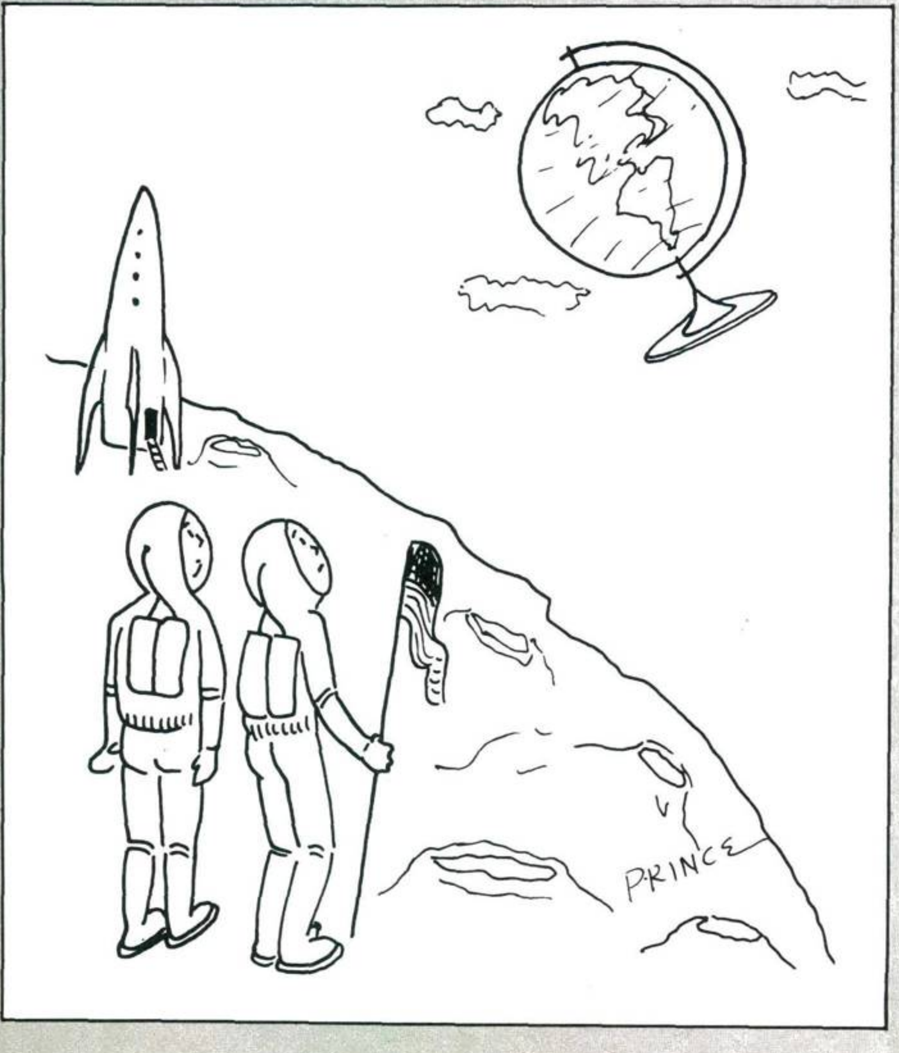
Jackson and Ryan have been welcoming scientists to follow up their hypothesis by finding evidence of disturbances in the North Atlantic region on that eventful day. William Beasley and Brian Tinsley, also of the University of Texas, recently responded — with negative results.

Examination of English records of minute air pressure changes on that date fails to reveal shock wave pulses radiating from the North Atlantic. So sensitive were these barometric readings that the Siberian shock waves (coming from much farther away than the calculated exit point) faithfully showed up three minutes after the blast.

Considering all evidence, a comet seems the likely culprit behind Tunguska's devastation. Containing mostly frozen gases mixed with nickle-iron and silicate pebbles, a comet nucleus hitting Earth would explosively vaporize from air friction before ever reaching ground. Small nickle globules found peppering the blast center support this idea.

A disintegrating comet should leave a cloud of debris in its wake, and eyewitness accounts of the disaster describe a thick dust trail following the fireball. A "mini" black hole would act like a cosmic vacuum cleaner instead, sucking in air and dust along the way. Ghostly glowing clouds appearing for nights after the event also suggest that the upper atmosphere was laced with fine cometary dust reflecting sunlight.

If the Tunguska incident was a comet collision, don't expect another megaton-like blast for at least 80 million years.



Heavenly Highball Discovered

Radio signals originating in a cosmic cloud containing ethyl alcohol have been discovered near the center of the Milky Way galaxy. Ethyl alcohol is the type of alcohol that you can drink — as opposed to methyl alcohol, a molecule discovered to exist between the stars in other radio astronomy experiments several years ago. The detection was made by a group of scientists at the National Radio Astronomy Observatory in West Virginia.

The newly found molecule is the most complex ever discovered by radio astronomers. It brings the total number of molecules known to exist in the diffuse clouds of gas and dust in space to 34, with about four unidentified species also found.

The existence of such molecules in space was undreamt of only a few decades ago, and proves that complex chemical processes actually do occur in the frigid depths of space between the stars. Until recently it was believed that such substances could be produced only in living organisms. This has profound implications for the origin of life on Earth, in that our planet could have been "seeded" from space — thus starting the processes that eventually lead to life.

The ethyl alcohol is embedded in clouds of gas and dust called nebulae, located near the center of the Milky Way galaxy where most of the other complex molecules have been detected. Since these clouds are about 25,000 light-years away, there does not appear to be any likelihood that we will soon want to lay a pipeline to funnel the stuff to Earth. To fill a glass with this celestial alcohol, you would have to drain millions of cubic miles of space.

The search for new space molecules continues to be a free-for-all with many researchers vying with each other as they scan the expanses of our galaxy. In the present discovery, no less than 13 astronomers are having their names associated with the find although certainly not that many were at the telescope when the detection was made.

The discovery of individual molecules in space may seem like an impossible feat, but in reality, radio astronomers are becoming fairly proficient at it. Each atom or molecule has a characteristic signature, detected by the radio telescopes as a specific wavelength of energy emitted by a cloud of those atoms. However, the wavelengths involved range from 1.8mm to 36cm in length.

The astronomer's problem is something like listening for a specific note from a single instrument in a symphony orchestra. It's almost impossible to do without a precision detector. In the laboratory the astronomer finds what wavelength his atom or molecule should be emitting. He then "tunes" the radio telescope to that wavelength. When it detects something, he can then be suspicious that the molecule indeed exists in space.

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Sol Spins in Different Gears

Astronomers have long been aware that the sun's equator rotates faster than the poles. But new observations by Robert Howard of Hale Observatories now suggest that our star may have an inner shell rotating slightly faster than the outer surface (or photosphere).

Clues for the new finding emerged from studies of tiny magnetic fields erupting along the sun's equator. Howard noticed that instead of standing perpendicular to the photosphere, magnetic field lines bend slightly backward from their direction of motion like trees in a strong wind. Howard believes such odd behavior means that the field lines are anchored to a faster moving inner shell. He points out that sunspots — known for their faster rotation rate — may also be tied to this mysterious subsurface region.

Howard's findings mark the conclusion of an intensive eight year solar magnetic field study. Using the 150 foot tower telescope at Mt. Wilson Observatory, coupled with a magnetograph — a device which maps and measures solar magnetism — he logged some 20 million observations.

Unlike Earth's tidy overall magnetic field, the sun accommodates many smaller fields hundreds to thousands of times stronger than Earth's. A compass would be about as useful on the sun as a weather vane in a tornado.

Howard observed that the sun's differential surface rotation continually launches bundles of magnetism on a ghostly migration from equator to poles. Only five percent of these wanderers ever reach their destination. The remaining fields are doomed to instant annihilation in collisions with bundles of opposite polarity.

His research also helps confirm a link between magnetic activity and the 11 year sunspot cycle — but raises additional puzzles. For example, at the cycle's peak — when the sun usually goes full blast into a fireworks display of flares, prominences, and sunspots — hot spots of activity prefer to congregate around negative fields. Why not positive areas as well?

Although the sun was due for maximum activity in 1971, its northern hemisphere alone held center stage. Until only recently the southern hemisphere remained stubbornly tranquil.

More Details Revealed On New Jovian Moon

Astronomers continue anxiously pinning down the orbit of what they believe is Jupiter's 13th moon, discovered in Sept. 1974 by Charles Kowal of Hale Observatories. They are working under a tight deadline as Earth's orbit carries them even farther away from the giant planet, making observations of the new moon increasingly difficult. Soon it will become invisible.

Early estimates placed the body 14 million miles from Jupiter — on the fringes of the planet's immense satellite system. Astronomers first thought that the 13th moon was orbiting retrograde (clockwise) along with Jupiter's four other outer moons — making it likely an asteroid scooped up by the huge world's powerful gravitational field.

Now Kaare Aksnes of the Smithsonian Astrophysical Observatory (SAO) has determined that the tiny moon orbits 7.8 million miles from Jupiter, completing an orbit in 282 days as it travels in a more normal, counterclockwise path (the direction all the planets and most moons follow). His results place the object in Jupiter's intermediate satellite zone, inhabited by three moons in steeply tilted and eccentric orbits.

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Piggyback Astrophotography

by
Leo C. Henzl Jr.

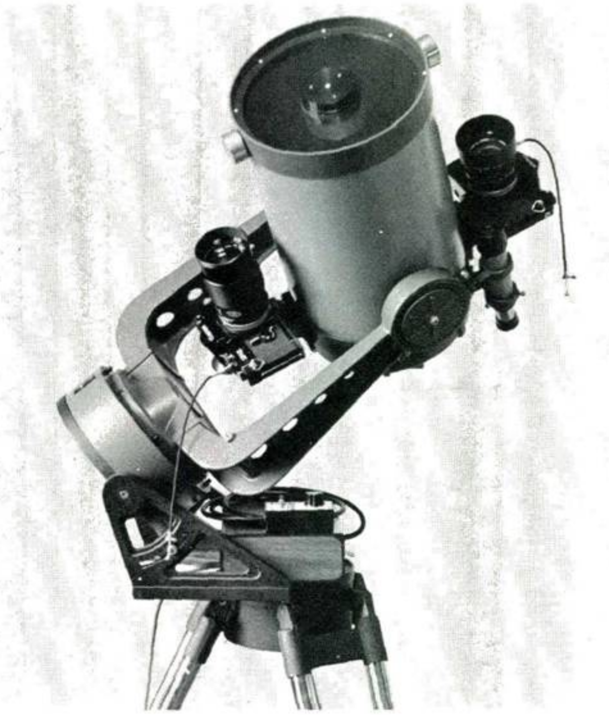
Remember the last time you tried star trail photography? It was easy — just open the shutter for a few minutes — no fuss or tricky details. All those gracefully curving streaks on the film are pretty, but after a while all star trail photos begin to look much the same. Of course, you can avoid the trailing by taking short exposures with a tripod mounted camera. Although this method can result in pleasing portraits of certain celestial subjects (see "Sky Photography Without A Telescope", November 1974), the chief limitation of such a set-up is that exposures must be of relatively short duration to "stop" the hourly apparent motion of the sky from east to west. Exposures of much more than 30 seconds render stars as streaks rather than points, and destroy the realistic effect you usually want.

Two unexpected visitors left their calling cards on this 15 minute piggyback photo of the constellation Orion taken with a 55mm lens at f/2. The red line is from a passing airplane, but the small streak below Betelgeuse is the glow of a vaporizing meteor. Photos such as this can be made with fairly modest equipment as described in this article.

Photograph by Ewell Schirmer

To really exploit that most marvelous property of film — its ability to build up a brilliant image of a virtually invisible object over an extended period of time — you need exposures much longer than those possible with a stationary camera. Mounting your camera piggyback on a clock driven telescope enables it to "pan" with the stars so that your shutter can remain open as long as sky conditions and your patience permit. Your telescope becomes, in effect, a moving platform for your camera.

Why, you might ask, shoot with your camera *atop* a telescope rather than *through* it? For one thing, many subjects are simply too large to fit onto 35mm film at the focus of a telescope, or are too dim for tolerable exposure times with the relatively long f-ratios of most telescopes. The often photographed North America nebula, for example, spans



"Piggyback" astrophotography derives its name from a setup such as this. Here, ordinary cameras have a free ride on the side of an eight inch Celestron telescope. If the telescope is properly aligned on the north celestial pole, the whole unit can precisely track the stars. The results are photos such as those on pages 60 and 74. Most telescope manufacturers offer an accessory mounting to enable you to attach your camera to the telescope.

several times the apparent extent of the full moon and is so low in surface brightness that it's all but invisible in any telescope. The nebula itself and surrounding star fields frame up nicely with a 135mm lens, however — and with a fast slide film, 20 minutes or so at f/2.8 will record it. A four inch f/15 refractor, on the other hand, is nearly five f/stops "slower" in photographic speed, and so would require 32 times the exposure for the same image density — 640 minutes (without allowing for reciprocity failure of the film). What's more, since the telescope could frame up only a portion of the nebula in a single photo, a two or three picture mosaic would be necessary to portray the subject in its entirety — a possible total exposure time on the order of 32 hours! For large objects of low brightness, piggyback photography is definitely the ticket.

To get started in piggyback photography, you'll need a simple bracket to mount your camera on your telescope. You can probably obtain this item from your telescope manufacturer at modest cost; but if not, several of our advertisers offer universal camera brackets of various kinds. Since the mounting requirements are simple — mainly, just that your camera point in the same general direction as your telescope — a little ingenuity and a trip to your local hardware store may save you a few dollars.

It might seem, with your camera suitably mounted, that you could simply pick a subject, lock your shutter open. and retire to the warmth of the indoors for the next half hour or so. However, the ultimate sharpness of your piggyback photos will depend to a large extent on how accurately the telescope tracks your chosen subject. Slight tracking anomalies which result from inexact polar alignment or from inherent drive errors go unnoticed in ordinary visual observation, but do record on your film, where they can add up to enlarged or deformed star images over the course of a long exposure.

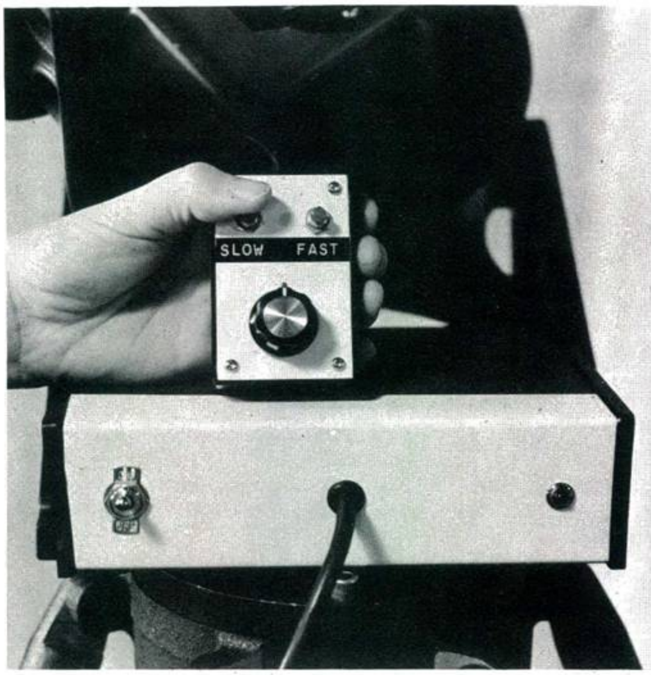
With the relatively short focal lengths of common camera optics, the requirements for accurate tracking in piggyback photography are not nearly as stringent as they are for guided photography through a telescope. Nevertheless, for the sharpest possible photos, you will need a method for detecting and correcting any image drift that occurs during your exposure. Since image drift may occur in either of two directions — in right ascension (east to west) or in declination (north to south) — an eyepiece equipped with cross hairs, like that in your finderscope, is ideal for monitoring your image. Special "guiding eyepieces" with the added advantage of illuminated cross hairs are available from several sources. With some telescopes, you may be able to simply rob your finder of its ocular temporarily for use in the main scope. For piggyback guiding, the magnification needn't be especially great; but in general, 50 power or more is desirable for reasonable accuracy. If you orient the cross hairs so that one axis corresponds to declination and the other to right ascension, you will have a very sensitive means of ascertaining both the direction and magnitude of any apparent image motion.

Now that you're able to detect image drift, what can you do about it? If a star image drifts gradually north or south along your declination cross hair, this indicates a need for more precise polar alignment. With a portable telescope and the possibility of your tripod or pier shifting slightly on soft ground in the course of an evening, it may be impossible to polar-align precisely enough to stop declination drift altogether. But you should be able to reduce it to the point where it is imperceptible in about one minute at 50 power. Accuracy of this sort may require a bit of initial fussing early in the evening, but it'll pay off in terms of better photos and more relaxed guiding. An adequately precise polar alignment procedure is described on pages and elsewhere in this issue.

Once you've reduced declination drift to the proportions described, it's just a matter of keeping your guide star centered north to south with a periodic turn of your declination slow motion control (if your telescope is so equipped). Without this control, things are a bit more difficult but not impossible. Keep a black card handy to cover your camera lens while re-centering your image, and remove it to continue your exposure when you're satisfied with image placement.

With the matter of declination drift under control, your next concern will be the performance of your clock drive. Just how accurate is it? If typical of most commercial units, its long-term average accuracy may be very good indeed — to the point, perhaps, where a return to your eyepiece after an hour's absence may still find an object right at field center. If, however, you monitor a star image continuously with your cross hairs ocular, you will probably find that it wanders a bit east and west of center on a fairly regular basis over shorter periods of time. This short-term or *periodic* error results from necessary gear and bearing clearances. which cause your drive to run momentarily a little slow or fast. It occurs to a greater or lesser extent with any clock driven telescope. How serious a problem it presents will depend on its magnitude, which with some instruments — especially larger ones — may be slight enough that a short focus camera lens won't resolve it. Generally, with telephoto lenses, or for the most critically sharp results even with your normal lens, you'll have to correct for it.

Unlike drift in declination which needs only occasional correction, periodic drive error may occur almost continuously — so it's not practical to compensate for it with a manual control. An electronic drive corrector is the answer here. Plugging in your telescope to one of these devices enables you to change the basic speed of your drive to compensate for any long-term inaccuracy or — with the instantaneous "fast" and "slow" buttons in its hand-held remote control — to speed up or slow your drive momentarily to correct for periodic error. A drive corrector also permits operation of your drive from a 12 volt battery in the field, and is generally handy for precise telescope movement — all in all, a most versatile accessory for a clock driven telescope.



A drive corrector is an essential accessory for quality astrophotography in the piggyback mode. This device allows the operator to correct for irregularities that are inherent in most telescope drive systems. The model shown here is marketed by DOAA Enterprises.

With the low numerical f-ratios of typical camera lenses, and the impressive performance of various color slide films described in a previous article ("Which Color Slide Film Should I Use?", October 1974), piggyback exposures tend to be of fairly modest duration. Precise exposure recommendations are impossible, owing to the wide variance in sky and weather conditions over various parts of the country. But as a starter, a location approximately 60 miles from Chicago permits an exposure of nearly 30 minutes at f/2.8 for near zenith photos with ultrafast GAF 500 film on the clearest of nights. Since piggyback photography is so well suited to portraying the tenuous beauty of extended nebulae and star clouds of very low surface brightness, your most rewarding results will come if a dark site is accessible to you.

One conclusion you're almost sure to draw in piggyback photography is that your camera lenses — which perform so faultlessly in normal photography — were not really designed for shooting stars at full aperture. It is not uncommon for a 50mm f/1.4 lens to produce noticeably aberrated star images over more than 50 percent of its field — with a progressive deterioration from center to edge. Wide-angle lenses are usually worst in this respect, with "normal" lenses a close second, and telephoto lenses usually the least aberrated of all. This is only a general rule, however, and there's really no way of predicting a given lens's performance on star images except by testing it. Different samples of the same lens often exhibit substantially varying performance — so if you're thinking of acquiring a lens specifically for astrophotography, it's not a bad idea to insist that your final purchase be subject to testing.

A half hour spent guiding a piggyback photo with your eye glued to a cross hair ocular can seem like an eternity on cold winter nights. The winter sky, however, is a veritable bonanza for the piggyback photographer — with its preponderance of open star clusters and rich nebulosities. We're sure you'll find the effort well worthwhile.

Leo Henzl is the Midwest technical sales representative for Celestron Pacific and Carson Astronomical Instruments, and devotes full time to astronomy and astrophotography — his lifelong interests. Before moving to his present home in Sandwich, Ill., he spent three years on Eastman Kodak's editorial staff in Rochester, N.Y. He is astrophotographic director of the Sandwich Astronomical Society.

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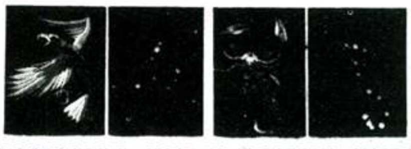

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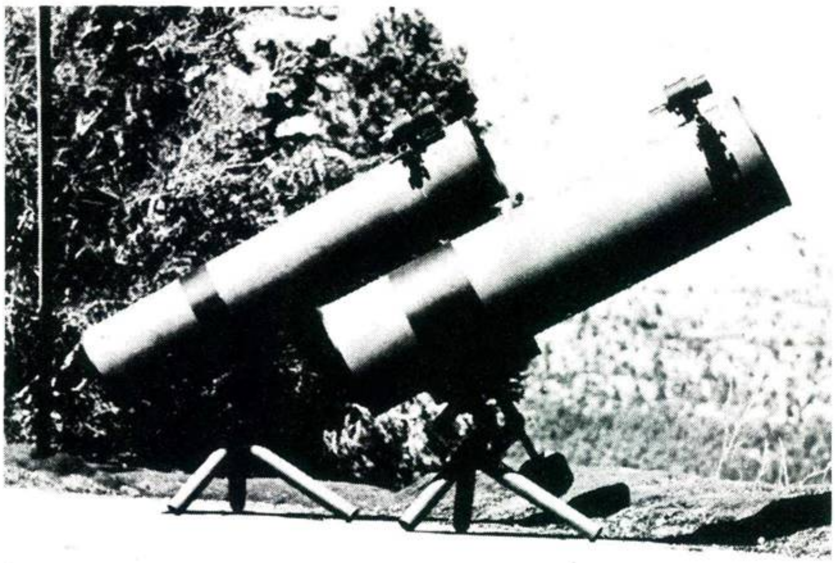

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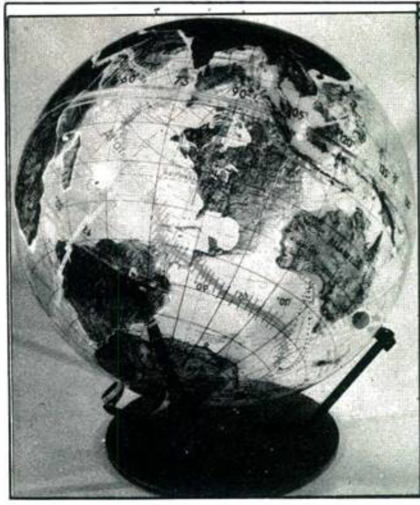

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STAR DOME

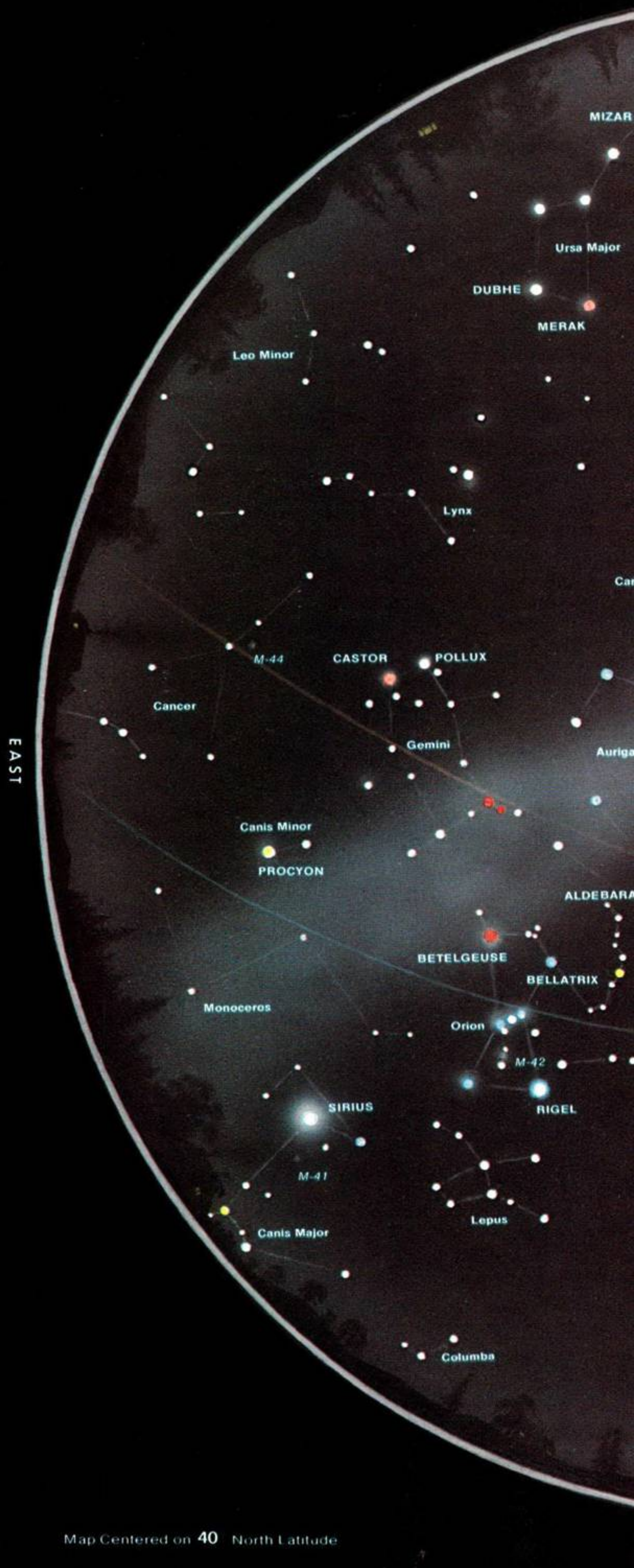
January

This is the new Star Dome. A number of factors led us to combine our old Star Dome and Constellation Close-Up departments. We wanted to expand both of them to give better coverage of the monthly sky scene than we could with two separate approaches. If you were initially disappointed at not seeing Constellation Close-Up in this issue — it's still here, but is now part of Star Dome. Here's the reasoning behind the change:

Star Dome was, in its old format, a monthly view of the sky as seen with the unaided eye with occasional tips on what to look for with binoculars. Then, separately in Constellation Close-Up, we moved to a specific area of the sky, concentrating on a bunch of objects in a particular constellation. On some occasions the constellation was loaded with interesting objects (like Cygnus) and on other occasions it was hard for us to talk about anything at all of interest (such as the constellation Libra). We were really at the mercy of the objects within the arbitrary constellation boundaries.

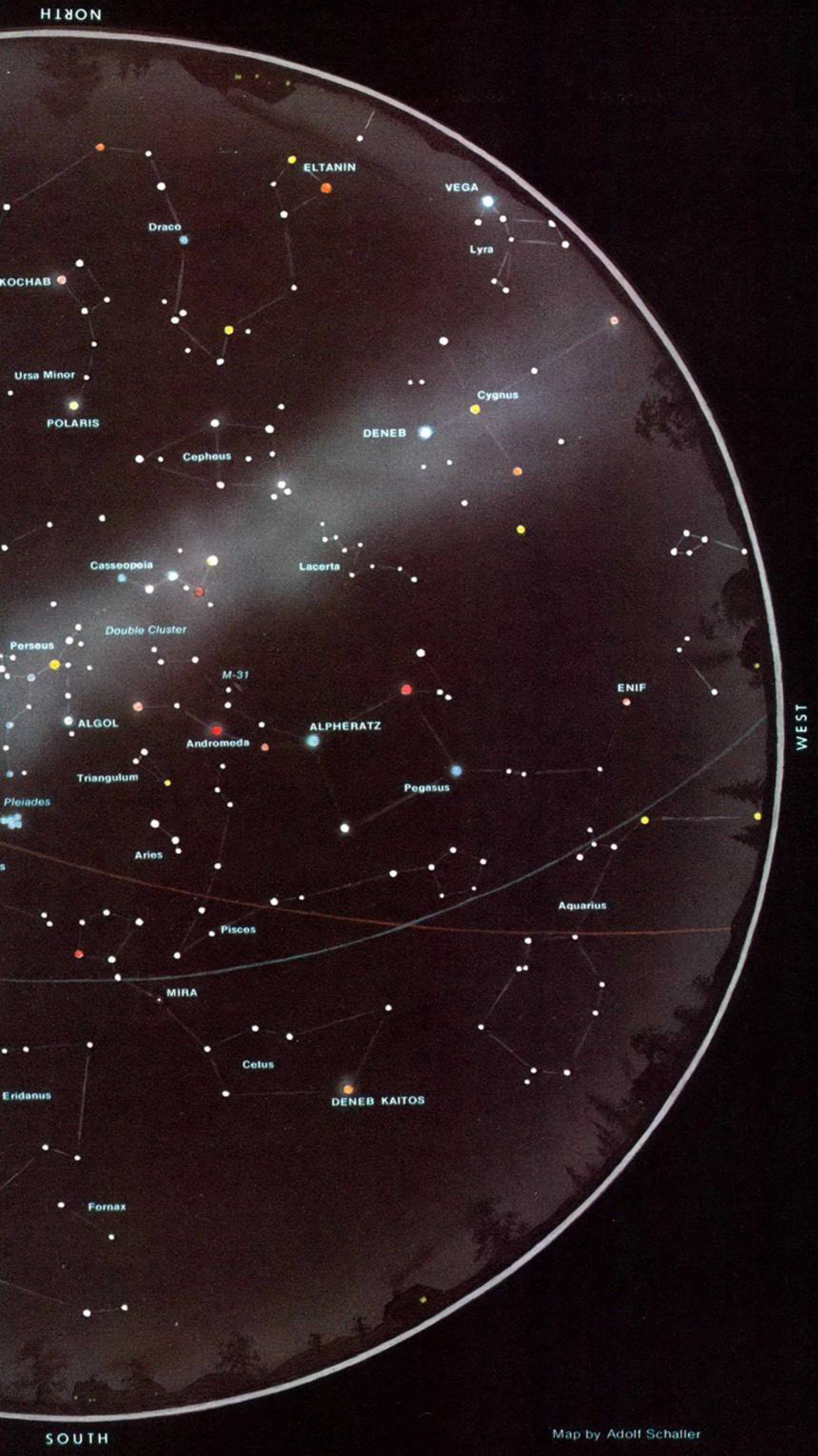
From now on, we will cover the sky each month in the following pattern: Our old Star Dome maps have been replaced by similar ones now in color. We have added an intermediate scale map of about 1/ 3 of the sky — the region of primary interest each month. Here we include more detail than the old Star Dome map had. Our third step is to have a Close-Up look at a section of that sky. The section will not necessarily be a constellation — although this month it happens to be. We may take half of a constellation or two or three constellations within the selected area depending on the number and variety of interesting objects. What we wanted to

continued on page 71

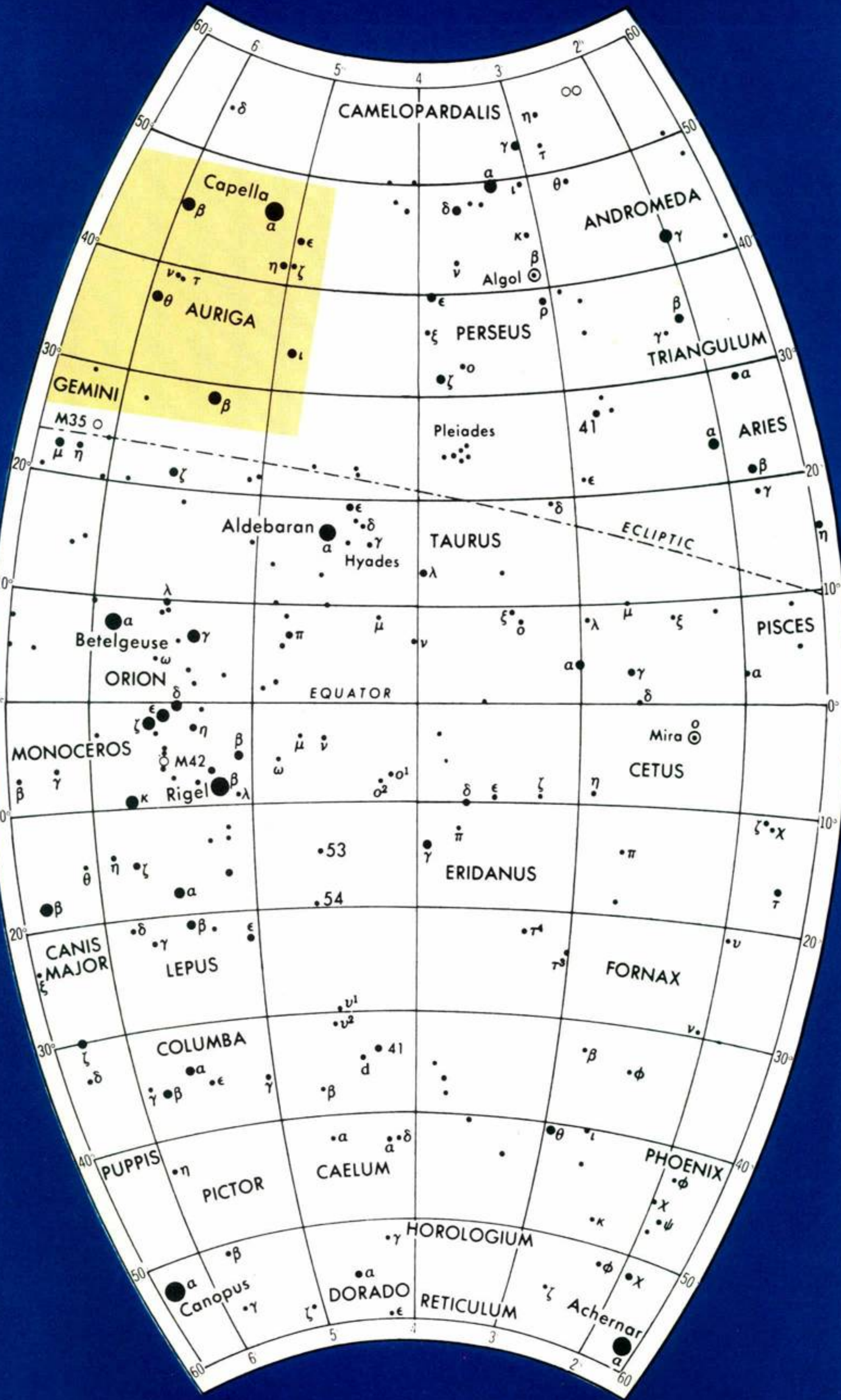

MIZAR
Ursa Major
DUBHE
MERAK
Leo Minor
Lynx
Car
M-44
CASTOR
POLLUX
Cancer
EAST
Gemini
Auriga
Canis Minor
PROCYON
ALDEBARA
BETELGEUSE
BELLATRIX
Monoceros
Orion
M-42
SIRIUS
RIGEL
M-41
Lepus
Canis Major
Columba

Map Centered on 40 North Latitude

Star Dome approximates the sky as it appears at 8 p.m. Local Standard Time on the first day of the current month. The same constellations are visible one hour earlier on the 15th. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder in Sky Almanac.


NORTH
ELTANIN
VEGA
Draco
Lyra
KOCHAB
Ursa Minor
Cygnus
POLARIS
DENEB
Cepheus
Casseopeia
Lacerta
Double Cluster
Perseus
M-31
ENIF
ALGOL
ALPHERATZ
Andromeda
WEST
Triangulum
Pegasus
Pleiades
Aries
Aquarius
Pisces
MIRA
Cetus
Eridanus
DENEB KAITOS
Fornax
SOUTH

Map by Adolf Schaller


CAMELOPARDALIS
Capella
AURIGA
GEMINI
M35
ANDROMEDA
Algol
PERSEUS
TRIANGULUM
ARIES
Pleiades
41
ECLIPTIC
Aldebaran
Hyades
TAURUS
Betelgeuse
ORION
EQUATOR
PISCES
MONOCEROS
M42
Rigel
Mira
CETUS
53
54
ERIDANUS
CANIS MAJOR
LEPUS
FORNAX
COLUMBA
41
PUPPIS
PICTOR
CAELUM
PHOENIX
HOROLOGIUM
Canopus
DORADO
RETICULUM
Achernar
60°
50°
40°
30°
20°
10°
0°
10°
20°
30°
40°
50°
60°
6
5
4
3
2

Star Magnitudes

● ● ● ● ● ● • • · ·

—1 0 1 1½ 2 2½ 3 3½ 4 5

○ Cluster or Nebula

⊙ Variable Star

+ Nova

Stars in each constellation are indicated, in order of brightness, with the Greek Alphabet.

α	Alpha	η	Eta	ν	Nu	τ	Tau
β	Beta	θ	Theta	ξ	Xi	υ	Upsilon
γ	Gamma	ι	Iota	ο	Omicron	φ	Phi
δ	Delta	κ	Kappa	π	Pi	χ	Chi
ε	Epsilon	λ	Lambda	ρ	Rho	ψ	Psi
ζ	Zeta	μ	Mu	σ	Sigma	ω	Omega

Map from **Guideposts to the Stars**; reprinted permission of MacMillan Publishing Co., ©1972 by Leslie C. Peltier.

do was to move from the unaided eye appearance of the sky to the binocular appearance of the sky, and finally to a telescopic examination of a specific area. This gives us new flexibility — to be able to focus on regions and objects of interest — that were missing before.

So here it is — the new Star Dome, a monthly in-depth examination of the evening celestial objects beyond our solar system. We hope you approve of our changes and hope that you will give us your comments and suggestions.

Let's now take our backyard look at the whole sky. January is the first month where Orion rides high and the winter Milky Way passes nearly overhead. Although not quite as rich as the summer Milky Way, the star clouds of winter are impressive on a crisp, clear winter night. The Milky Way gives luster to Cassiopeia and Perseus — discussed in the last two installments of the old Constellation Close-Up. Those constellations were loaded with interesting objects because they are in the band of the Milky Way. There are more objects to see in the plane of the Milky Way than there are in other directions; therefore, these constellations have more than their share of goodies. And the same can be said for the Auriga region that we'll look into in more detail later on.

In the lead article in this issue George Abell describes the gigantic cities of stars like our own galaxy that exist throughout the known universe. Everything that we see in the night sky from the northern hemisphere is part of the Milky Way galaxy with only one exception — M-31, the Andromeda galaxy, which appears like an out of focus fifth magnitude star in the constellation Andromeda. Apart from that, the night sky is the interior of the Milky Way in our region spread out before us.

Let's suppose we replaced the brightest star in the night sky, Sirius, with our sun. It would then not appear at -1.4 magnitude (the brightness we see Sirius), but at a much fainter +2.2. Obviously Sirius is actually much more luminous than the sun. Let's play this game with other stars replacing them with the sun and see what happens. Sirius' nearby companion Mirzam is magnitude +2.0 to our eyes — a respectable star which just happens to be overshadowed by Sirius. But Mirzam is much farther away than Sirius and is intrinsically much brighter. If the sun replaced Mirzam, it would be magnitude +11 — far below the naked eye visibility limit of +6. Let's try it once more with Procyon in Canis Minor. The sun replacing Procyon would give us a star of magnitude +2.5, not much different than Procyon's present +0.4. In every case, our sun is a fainter star than the star it replaces.

This chart is a detailed version of the central and southern sections of the map on pages 68 and 69. The box identifies the zone selected for detailed examination in this month's Close-Up section of this department.

We could go on making comparisons such as this and would find that in practically every instance the sun would shine at inferior brilliance to the star that we see in the sky now. The conclusion we can draw is that almost all of the stars that we see in the night sky are the blazing lights of the galaxy. Fainter suns like ours are reduced to obscurity in the shadows of these great luminaries. This particularly comes into focus in the case of stars like Rigel in Orion — the fifth brightest star in the night sky (from the northern hemisphere).

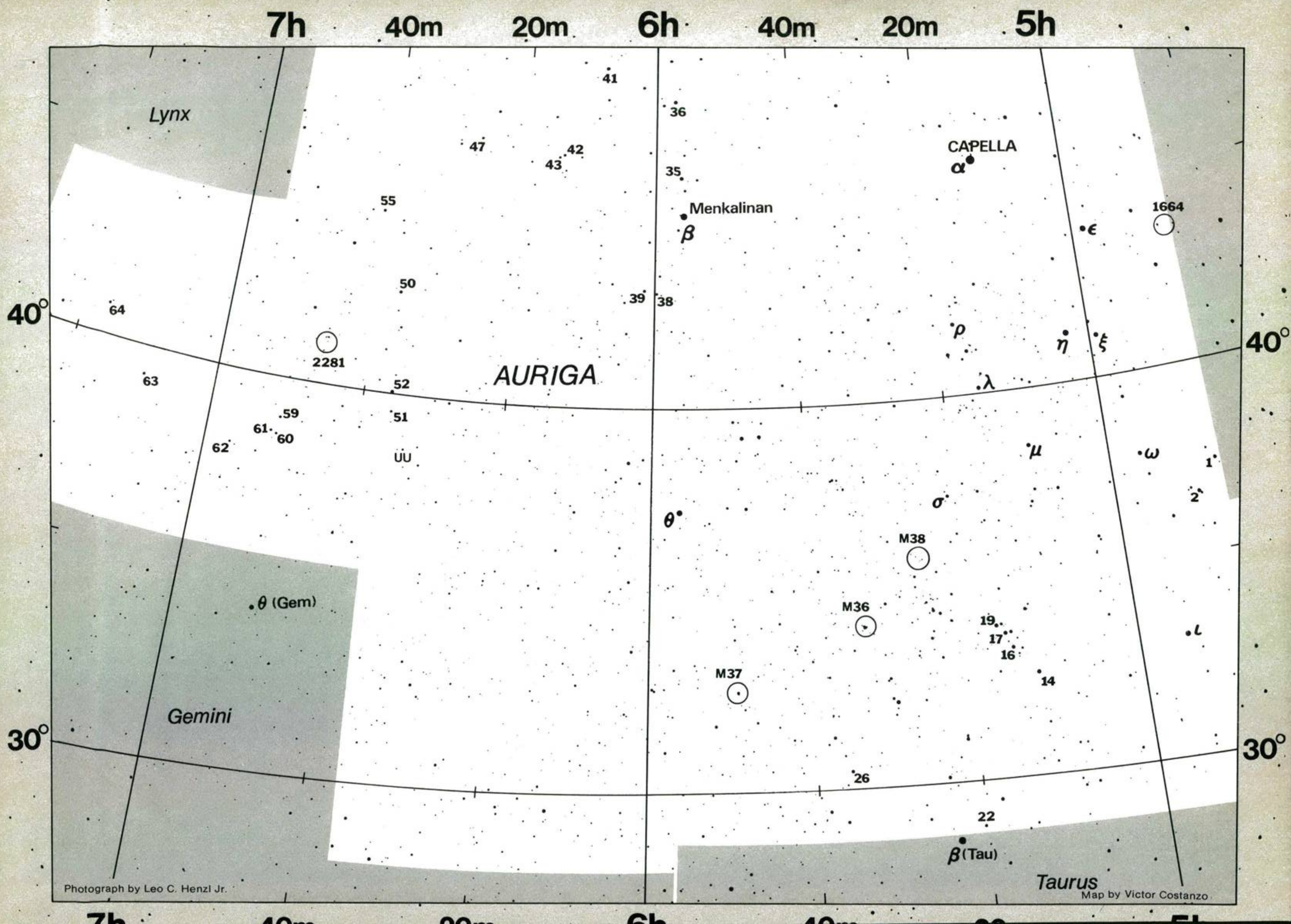
Rigel shines with 55,000 times the brilliance of the sun, even though we are viewing it from a distance of 900 light-years — about 100 times farther away than Sirius and Procyon and the same distance as Mirzam. This means that Rigel would be a first magnitude star from anywhere within a sphere of space 1,000 light-years in radius. That's a significant portion of the galaxy and yet the sun would appear as a first magnitude star only out to a distance of six light-years. So the giant suns, although they are extremely rare, nevertheless make up for that by so totally exceeding the brilliance of the multitudes of fainter stars.

The point we're trying to make is that we really get a distorted view of our galaxy when we look into the night sky. We are only seeing the superluminaries. Millions of fainter suns are simply invisible to us. Some of the faintest stars can't be seen even with the world's largest telescopes at distances greater than about 50 light-years. It's a sobering concept just to realize how little we actually see when we look up at the sky at night compared to what is actually there — and we haven't even mentioned the millions of galaxies that are beyond our own.

Close-Up on the Auriga Region

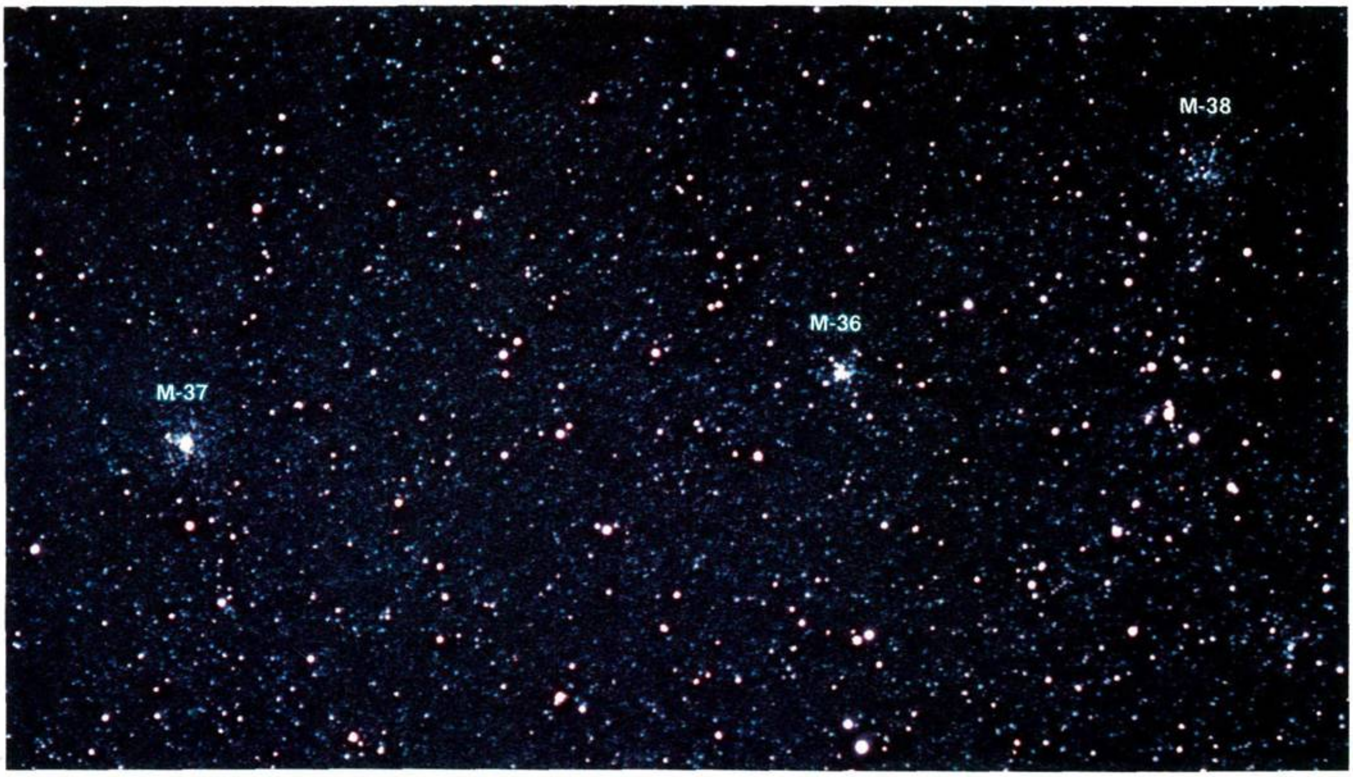
This month and in the months ahead we will be selecting rectangular segments of the sky, about 20 by 30 degrees in size, for more detailed examination. This month's region is shown on the map on page 70 and is illustrated in detail on the map and photograph on pages 72 and 73. Both the photo and the guide map on those pages show stars down to magnitude 8.5 — about the limit of a good pair of binoculars.

The numbering and lettering system of the chart may require some explanation. The Greek lettering is the same system used on the map on page 70. Alpha (α), or Capella, would probably be a good point to link up the detailed map with the chart on page 70. The numbering system within the constellation is a star designation utilized when the Greek alphabet ran out. The numbered stars are known as 36 Aurigae, for example. The circles represent star


7h
40m
20m
6h
40m
20m
5h
40°
40°
30°
30°
Lynx
AURIGA
Gemini
Taurus
CAPELLA
α
Menkalinan
β
1664
ε
ρ
η
ξ
λ
μ
ω
1
2
σ
θ
M38
M36
M37
19
17
16
14
ι
26
22
β (Tau)
41
36
47
42
43
35
55
50
39
38
64
2281
63
52
59
51
61
60
62
UU
θ (Gem)

Photograph by Leo C. Henzl Jr.

Map by Victor Costanzo



Photograph by Leo C. Henzl Jr.

clusters within our own galaxy — three of which are Messier clusters and are discussed in detail below.

The major configuration of Auriga is a pentagon formed by Capella, Menkalinan, Theta (θ), Beta (β), Tauri and Iota (ι). The pentagon is really a "cheat" because we use one star from Taurus to make it. But it's a distinctive configuration that will soon become familiar to you if it isn't already. The Milky Way runs through this region diagonally from the chart's upper right to bottom center with the three Messier clusters embedded near the center of the Milky Way. The density of stars in that area of the chart is much greater than the upper left which is well out of the plane of the Milky Way, once again confirming the fact that we're looking in toward the populated zone of our galaxy.

Eyepiece Impressions

Each month in this section of Star Dome we will select a variety of celestial objects in our Close-Up region. These objects will always include one or two visible in very small telescopes. This month we have one double star, one unusually colored star and three galactic star clusters.

UU Aurigae

The pulsating "carbon" star UU Aurigae is perhaps the reddest star in the sky. Usually visible to the unaided eye, this highly colored object forms a triangle with Beta (β) and Theta (θ). A finderscope directed to its location in the sky as shown on our chart will reveal 51 and 52 Aurigae and UU nearby. Its vivid red hue is obvious with even the slightest optical aid, making identification easy.

This star is a member of a class called semiregular variables. It changes from magnitude 5.1 to 6.8 in an approximate period of 235 days. But the cycle is not very reliable — hence the classification. UU is one of the sky's brightest representatives of the rare spectral type N. Unlike many of the deep red stars of this class (which sometimes drop to below the limit of even large amateur instruments), UU's magnitude range is small enough that you can always count on it being there when you want to look at it.

A useful technique in observing the hues of stars like UU and the colorful components of double and multiple stars is to slightly defocus the image seen in the telescope (preferably outside of, rather than inside, the focus). This often makes colors more obvious, especially for those whose eyes are not yet trained for such observations. Another method of enhancing color perception is the use of high magnification on a small telescope (a three or four inch at 150 power, for example), producing diffraction disks of the stars instead of point images.

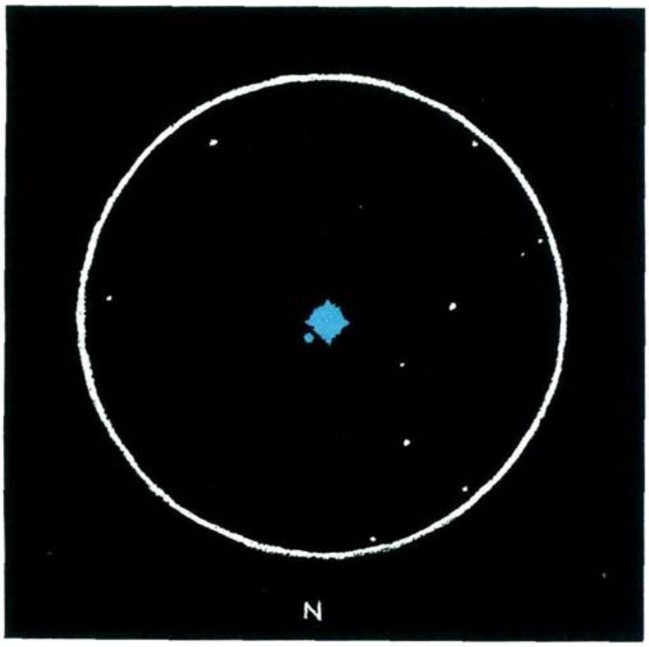
Theta (θ) Aurigae

This beautiful double star is a bright unequal pair consisting of a 2.7 magnitude primary and a seventh magnitude companion. This object provides a striking light contrast, but the components are separated by just three seconds of arc making Theta difficult to split in anything less than six inches aperture. In 10 and 12 inch telescopes, this double is one of the finest unequal pairs in the sky. Both stars are blue-white in color and require good to excellent seeing (image steadiness) for a pleasing view. (There is, incidentally, an entire class of deep sky objects that are stunningly beautiful, but difficult to observe. Among doubles, Sirius and Antares are other examples in addition to Theta Aurigae.)

M-36, M-37 and M-38

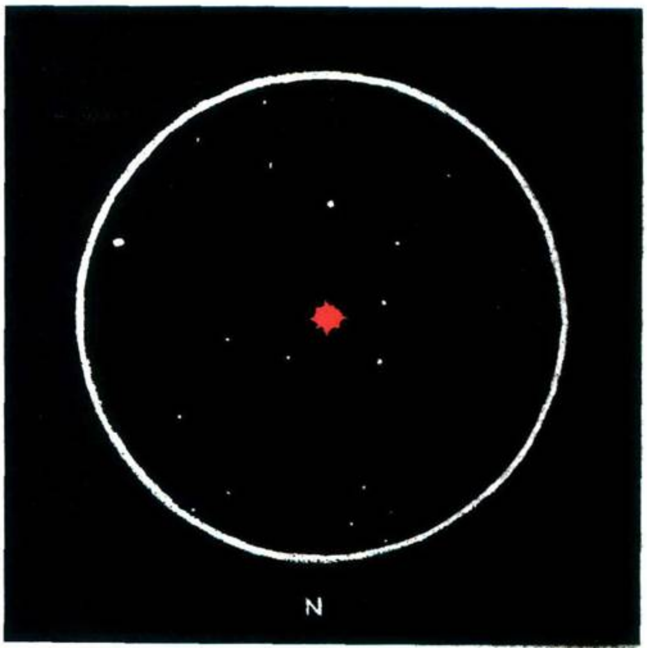
These three showpieces are glittering star clusters of the open or galactic type from Messier's famous list. Each can easily be picked up in finders or binoculars and all three are striking objects in telescopes of four inches and larger. M-36 and M-37 are four degrees apart while M-38 is two degrees northeast of M-36. Our chart should make finding them easy. Even though these "celestial jewel boxes" all belong to the same class, each has its own distinctive characteristics. M-36 contains some 60 stars in an area 12 minutes of arc in diameter and has an integrated (total) magnitude of 6.3, near the naked eye limit in clear skies. It appears as a scattering of both bright and faint stars, and is best seen with low powers. As with most deep sky objects, a dark transparent moonless night is needed for an optimum view. Webb called this cluster a "beautiful assemblage of stars very regularly arranged".

M-37 is a rich uniform glow of relatively faint stars — more than 150 of them in an area 20 minutes in extent. Its integrated magnitude of 6.2 makes it the brightest of the three clusters, but M-36 seems more conspicuous in the finder. There is a fairly bright ninth magnitude reddish-orange star near the center of M-37, as is frequently the case with open clusters (M-11, M-41, M-50, etc.), leading us to wonder if this is more than just pure coincidence? Early observers like John Herschel also remarked about the occurrence of these ruddy stars near the centers of many clusters. Where such brighter stars do appear, they should be used for critical focusing on the surrounding cluster — this being especially useful on faint and hard to resolve objects. In clusters not having them, nearby field stars can serve the same purpose. M-37 is well resolved in a three inch refractor or four inch reflector at 45 power and takes higher magnification well. Smyth called this cluster "a magnificent object", and Webb said "the whole field being strewed, as it were, with sparkling gold dust". M-37 is certainly one of the finest objects of its class anywhere in the sky.



Sketch by James Mullaney

Theta Aurigae is depicted as seen through a 10 inch reflector at 150 power. The diameter of the field of view is about 20 minutes of arc. See text for details.

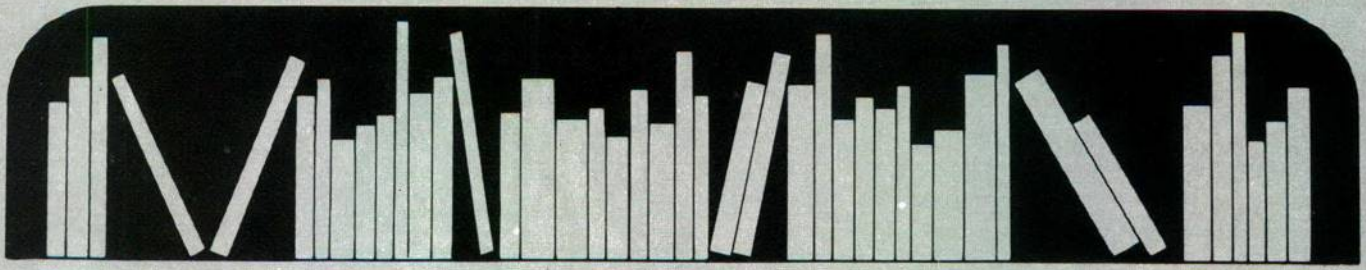


Sketch by James Mullaney

The variable star UU Aurigae shows up vividly red in a small telescope. Here, the view through a four inch reflector at 45 power is illustrated. The field of view is one degree in diameter. North is at bottom and west to the left to duplicate the view in most astronomical instruments.

Last of this celestial trio and faintest at magnitude 7.4, M-38 contains approximately 100 stars in a 20 minute diameter. Its brighter stars are arranged in a rough "X" or cross, with the fainter ones scattered about it. Again, the best views are with low powers and a wide field of view. All three clusters are approximately 4,000 light-years from us, embedded in the glow of the Milky Way.

With the possible exception of double and multiple stars, open clusters are probably the easiest and most rewarding deep sky objects for small telescopes. Their visual appearance in such instruments is often better than in any observatory photograph! Under good atmospheric conditions, hosts of individual pinpoints of light — each a distant sun in a celestial commune — appear as glittering diamonds floating in the black void of space.



ASTRONOMY REVIEWS

Apollo

by RUSSELL E. CHAPPELL

65 pages, paperback, $2.65*
U.S. Government Printing Office (1974)

The spectacular photography which was one of the by-products of the United States space program may yet prove to have some of the most far reaching effects on our civilization. The pictures brought home to millions of Earth dwellers the real image of the fragile blue Earth, the desolate neighbor world called the moon, and the immensity of empty space surrounding them. Our conception of our planet and our place on it will never again be the same.

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If the text suffers any shortcomings (and it is, mainly, just an accompaniment for the photographs), it is that the story of the space age is reviewed with hardly a mention of the whole reason for the Apollo project — the technical-scientific-political-prestige competition between Russia and America which resulted in the space race. It is a very nearsighted book in which a chapter entitled "Man Dares to Orbit" chronicles the U. S. Mercury flights but fails to give credit to Major Yuri Gagarin, the Russian cosmonaut who was the first man who really dared to orbit Earth. The fact that President John F. Kennedy committed the U. S. to the Apollo program only weeks after this spectacular Soviet space triumph is glossed over in the NASA booklet.

But the details of historical truth are already well documented in a dozen books now available. In none of them, however, is such a stunning collection of photographs available at so reasonable a price. This booklet is perfect to own or to give as a gift. NASA did a fine job with Apollo and has done a fine job in coordinating the publication of this visual delight. Get yourself a copy!

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* * *

The Invisible Universe

by GERRIT L. VERSCHUUR

189 pages, paperback, $5.90
Springer-Verlag (1974)

This has to rank as one of the most important books in popular astronomical writing published in many years. In under 200 pages, the author has provided us with a concise, lucid overview of a discipline that has recently come into its own. His description of radio astronomy's history, its methods, its instrumentation, its advantages over other fields as well as its disadvantages, and its role as a partner with those other fields, qualify this book as a classic. It does for radio astronomy what **The Stars in Their Courses** by Jeans or **Frontiers in Astronomy** by Hoyle did for optical astronomy.

To fully appreciate Verschuur's achievement, we would do well to contemplate the significance of his title. He has to describe a subject that is totally foreign to human senses. We do not naturally "see" or "hear" the radio universe. So the task of making that universe more visible to the layman is considerably more challenging than that faced by those who write about the optical universe.

From the outset, **The Invisible Universe** strikes the fancy of the reader by answering many of the questions that inevitably come to mind about the business of receiving and converting long-wave emissions from outer space into meaningful information. How do we know the source of radio waves? How can we determine the size of the objects producing radio energy? Why are radio telescopes built the way they are? These are just a few of the questions dealt with in the opening pages.

The discussion of resolving power is outstanding. In fact, it isn't long before we readers begin to transfer some of the mystique and romance that has hitherto been the private possession of optical astronomy and instruments, to radio astronomy and its instruments. And this is a very remarkable accomplishment by the writer.

A short but lively history of radio astronomy leads into a discussion of the radio sun and the radio solar system. Later we join in the discovery and investigation of an old friend in a new costume — the Milky Way.

We then come to radio astronomy's great triumphs — the discoveries of quasars, pulsars, and interstellar molecules. Here Verschuur's abilities as a storyteller are revealed both by his sharp and clear analysis of the human side of science, and by his explanations of the events themselves. His description of the problems involved in establishing long base line interferometers between the United States and the Soviet Union is delightful.

We are taken on a tour of major radio observatories throughout the world and are given a glance at some of the designs and dreams of the future. Of particular interest in a succeeding chapter is his discussion of how a radio astronomer makes his observations and studies the data. The book concludes with a short section on the question of life in the universe — which, although inevitable in a discussion of radio astronomy, seems strangely anticlimactic in **The Invisible Universe**. As the author confesses, "The subject of this chapter (on life in the universe) could easily be expanded into a book...."

No book is perfect, but the flaws in this one are few. Some confusion is possible during an explanation of how electrons change their spins and emit radio energy. The confusion arises out of the amount of time that elapses between such changes, and the use of the word "random" to describe that time — while at the same time introducing two disdistinct time frames (400 years and 11 million years). Elsewhere, the rotation of the Milky Way is listed as taking three billion years (it should have been about 250 million years), and electrons are described as traveling at the speed of light (they don't and can't!). One curious error sees the northern and southern lights referred to as *corona* borealis — a term which, had it not already been applied to a constellation of the northern sky, might have been even more appropriate for those phenomena than aurora borealis. (Readers are reminded that corona means crown, while aurora means dawn.) Coronal forms are often displayed by the northern and southern lights.

The Invisible Universe should be part of the library of everyone interested in the universe.

◆

Pictorial Guide to the Planets

by JOSEPH H. JACKSON

248 pages, hardcover, $10.00
Thomas Y. Crowell Co. (1973)

Astronomer Carl Sagan wrote in last June's issue that today's space probes hang like swords of Damocles over planetary theorists. Sagan can put planet books under those swords too. Just as some astronomers find their cherished theories knocked down by incoming data from new planetary probes, many of today's solar system texts suffer from overnight obsolescence.

Pictorial Guide to the Planets is an especially dismal casualty. Compared with its first edition (1965), the scarcity of new information doesn't justify the cover jacket's promise of a "complete and up-to-date picture of the planets".

Already Mariner 10's spectacular double mission to Venus and Mercury leaves the text's discussion of the inner planets hopelessly outdated. Jupiter information, unchanged from the earlier edition, also looks archaic in light of Pioneer 10's odyssey.

The scant attention given to planetary missions preceding the volume's publication is unforgivable. For example, readers deserve a more detailed portrayal of Mariner 9's revolutionary findings about Mars than just a few spliced-in sentences. The moon gets similar treatment, and Apollo landings are mentioned in scattered paragraphs with little emphasis on their intriguing discoveries.

A welcomed improvement is a 36-page supplement of Apollo, Mariner 9, and other NASA photographs. (But will they please print the satellite view of the mid-Atlantic states right side up?!) Compared to some other solar system books this one is not as visually dynamic as its title suggests — for example, color prints fill only two pages.

Pictorial Guide to the Planets is useful only for historical reference. Readers hungry for a concise text on the hottest new planetary findings had better forget it — at least for the near future, since space probes are still strongly reshaping our solar system concepts.

◆

Soviets in Space

by PETER SMOLDERS
translated by MARIAN POWELL

286 pages, hardcover, $9.95
Taplinger Publishing Co. (1973)

The Soviet space program is the proverbial "riddle wrapped in a puzzle inside an enigma". Moscow carefully orchestrates publicity about its space achievements to put the best foot forward, prove the "superiority of socialism", and conceal failures and setbacks which might detract from that superiority. Finding the reality behind the contrived image is a difficult if not impossible task.

Peter Smolders' book, while seriously flawed in some crucial areas, can be a valuable source of information for Western readers trying to get background information behind the space headlines of the 1970s. The author, a Dutch space specialist, has excellent contacts with Soviet space officials and cosmonauts. He has not been too probing or too critical of the official line, and has written nothing here to offend his Russian friends.

Much of the valuable information in this thorough and complete chronology of the Russian space program is found in the excellent photos, sketches, and schematics — most of which have never been seen before outside of Russian publications. Unfortunately, Smolders lifted (or copied) most of these directly from Soviet sources. It might have been better if the author had given credit to these original sources, lest an unwary reader suspect that the artwork is all his (some is).

But far too often, Smolders also lifts his text directly from the original sources. This questionable policy trips him up, as he deserves. His language even in translation often sounds like a bulletin from Moscow. Language like "the great socialist motherland" and the "seven ton Soyuz colossus" (compared to the 100 ton "makeshift" Skylab) reveals both the author's sources and his slant.

He is far too uncritical of all official announcements. He "gives the Russians the benefit of the doubt", in his own words, and he misses out on insights that a little bit of critical checking or comparison could have revealed.

Did the first space pilot, the late Yuri Gagarin, land in his space capsule or eject from it during the final descent and land by personal parachute (thus technically disqualifying him from an international flight record)? The Russians, to claim that record, insisted that he rode the ship down — even though all previous unmanned tests, and all subsequent manned flights, involved ejecting the pilot a few minutes before touchdown. Western experts, for various reasons, have long suspected that Gagarin, too, ejected. Soviet press releases are contradictory, but Smolders didn't notice — or say so if he did; rather, he just repeats the official announcements.

The wide extent of Russia's massive military space effort and the absurd lie by Moscow that it doesn't even exist is not discussed at any length. Smolders devotes two paragraphs to Soviet "killer-satellites" and "orbital H-bombs", but finds some excuse for them and doesn't mention that in these systems the Russians have real space "firsts" as the United States has built nothing like them. Elsewhere the author seems to enjoy extolling the long list of Soviet space "firsts" (some of them counterfeit) whenever they can be used to show up the U.S.; American firsts are ignored.

The book is clearly not the full story, but a lot of valuable facts are accessible. Keeping in mind the author's biases, a critical reader can get much from this book. But the Soviet space program remains as great a riddle as ever. And this book, which attempts to explain it, is a failure.

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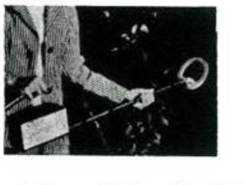

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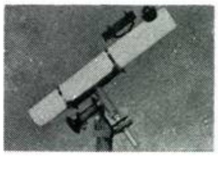

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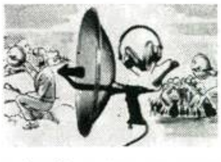

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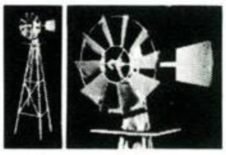

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